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[656]

Competition by roads, waterways and airways.

(Continuation) (1).

Spain, British India, French Indo-China and French West-Africa.

SPAIN.

I. — Steps taken by the Public Authorities.

In Spain, competition and the general railway position have been investigated in great detail.

Official organisations have been set up for this particular purpose by the Government. For example, the National Land Transport Conference, in 1932, was able to draft a bill as the result of its investigations. The essential clauses of this draft were included in the text proposed by the Commission for the co-ordination of railway and road transport, in 1934, which was published as No. 25 of the series issued by the General Railway Transport Association on this subject.

Pending the time these proposals become law, the Government issued, on the 19th July 1934, a decree authorising the Minister of Public Works to grant the railway companies concessions for working road transport. This decree is as follows :

Decree instituting a Commission for the Co-ordination of transport and authorising the Minister of Public Works to grant the Railway Companies concessions to operate road services.

Clause 1. — The Minister of Public Works, on the advice of the Co-ordination Commission as laid down in clause 3, is authorised to grant Class A concessions to the Railway Companies applying for them, according to the laws now in force, with the rights and obligations therein laid down, and in particular those under clause 22 of the Decree of the 22nd June 1929, relating to the suppression of B class services, which either partially or wholly duplicate the services offered by the said class A concessions. These concessions must conform with any decisions of the Cortès on the concessions and the future regime of the railways.

(1) See *Bulletin of the Railway Congress*, June to December, 1934.

Clause 2. — All services in connection with fairs, fetes, and markets, taxis and tourist services, authorised or which shall be authorised, must comply with the fiscal regulations and the decree of the 22nd June 1929, which still remains in force. Local and regional exceptions require the special authorisation of the Minister of Public Works.

Clause 3. — Under the title of Co-ordination Commission, an advisory organisation attached to the General Management of Railways, Tramways and Road Transport has been set up. This will be composed of one representative from each of the Ministries of Public Works, Finance, Communications, and Industry and Commerce, two delegates representing the Chamber of Transport, and two others the General Railway Transport Association.

This Commission will be presided over by the General Manager of the Railways, Tramways and Road Transport Department, and will have as secretary the Head of the Road Transport section of the said General Management.

Clause 4. — The Commission will report on all demands for new lines, appeals concerning existing lines, and, in general, will put forward its opinions or suggestions on all matters relating to transport co-ordination.

It will decide in each case whether the class A concessions asked for are parallel to or in competition with the railway, and also on the minimum length to which the facilities provided by this decree apply; requests for class A concessions which do not comply with the conditions laid down by the Commission shall be refused.

Within 30 days of its formation, the Commission shall submit to the Minister of Public Works the proposed organisation and regulation of its services and suggested procedure, at the same time reporting without delay all urgent matters within its competency.

Clause 5. — All resolutions of the Commission shall be considered as propositions to the Minister of Public Works, who can approve or reject them.

II. — Steps taken by the Railway Companies.

The unification measures taken by the Madrid-Saragossa & Alicante Railway and the North of Spain Railway include the setting up of a common research office.

This office has set up a joint railway and road transport co-ordination service, the main objects of which are :

1. to accumulate data on the subject of co-ordination, with statistical card indexes and files dealing with every motor service and all combined passenger and goods transport services;

2. to enquire into the relations between the railway and the passenger and goods road services, and into the abandonment of lines, in agreement, if need be, with the Operating and Commercial Departments of the North of Spain Railway and the Traffic and Commercial Services of the Madrid-Saragossa & Alicante Railway;

3. to communicate with the State, provinces and towns in so far as road transport is concerned;

4. to carry out contracts made by the headquarters and subsidiary offices and the combined departments of the railways with other methods of transport, in agreement with the commercial departments responsible for rates questions;

5. to control the transport service and thereby link up the central or subsidiary offices and the stations;

6. to make investigations and reports, and to manage and supervise the road services conceded to the North of Spain and Madrid-Saragossa & Alicante Companies, operated directly or by an ancillary company;

7. to make investigations into combined, feeder, or parallel services, with existing road transport firms;

8. to consider the introduction of combined tourist services;

9. to negociate, and make agreements, with the National Tourist Office and similar foreign organisations in order to stimulate advertising and develop the tourist traffic currents in districts served by the North of Spain and Madrid-Saragossa & Alicante Railways;

10. to handle propaganda and publicity dealing with the co-ordination of transport;

11. to maintain regular and cordial relations with legally authorised transport undertakings, respecting their vested interests and thus assuring their support when needed against interfering firms which, by seizing traffic in an obviously illicite way, harm the railways working under a lawful concession.

The best results are expected from the work of this service which has its agents in all districts where the co-ordination question arises, particularly if the public authorities decide to pass adequate legislation to prevent clandestine services and to divide up the traffic fairly from the fiscal, legal, and administrative points of view.

ITALY.

As an addition to the information supplied previously (see Bulletin for December 1934, p. 1270), the *Italian State Railways* advise us that, with regard to the cartage services, a bill has now been brought in, the object of which is the regulation of cartage services worked on behalf of a third party.

BRITISH INDIA.

The *Bengal Nagpur Railway* informs us that in addition to the steps already taken to fight road and waterway competition, the following questions are now being analyzed :

a) Terminal taxation on rail borne traffic in competition with road traffic, and

b) Port-to-port rates in competition with sea-borne traffic.

FRENCH INDO-CHINA.

The French Indo-China and Yunnan Railway Company reports, as measures taken during the second quarter of this year, various changes of rates : introduction of special reduced rates for passenger services between Hanoi and Hai-Fong, new reductions or extension of the period during which reductions already granted on special fixed rates applicable to various classes of traffic affected by competition, remain in force.

FRENCH WEST AFRICA.

Dakar-Niger Railway.

The information given below is taken from a note sent us by the Inspector General of Public Works, in French West Africa.

To diminish the effects of motor competition, which proved to be particularly serious during the years 1932 and 1933, the *Dakar-Niger* Railway has considered, or put into practical application, a number of measures intended to recover all or part of the traffic lost.

These measures are :

1. Acceleration of the trains and adaptation of their frequency and the conveniences offered, to the needs of the passengers.

2. Introduction of new passenger and goods rates to meet the new circumstances.

3. Acceleration of goods transport.

Each of these three points is analysed below.

1. *Acceleration of the trains and adaptation of their frequency and the conveniences offered, to the needs of the passengers.*

Whenever possible, the average speed of the regular trains has been increased; this applies to the Sudan weekly express train, and the daily service between Dakar and Saint-Louis (262 km. = 163 miles).

On the other hand, fast light trains have been put into service between certain stations where the passenger and parcels traffic is of particular importance, over routes parallelled by road services. This applies to the semi-express weekly trains between Dakar, Kayes and Bamako.

For small and medium distances, passenger coaches have been added to some of the goods trains.

Finally, on certain occasions (markets, fetes, etc.) when the number of passengers makes it possible, shuttle or special trains have also been run.

Comfort has also been considered; the « couchettes » coach in the semi-express trains has been replaced by a sleeping car, and a buffet car has been added to these trains for the use of 1st, 2nd and 3rd class passengers.

In order to speed up this traffic and provide greater flexibility, and also because of the reduced rates thereby made possible, rail motor coaches have been considered. Investigations are in hand at the present time to see which type is best suited to the gradients of the line and the traffic to be worked.

Although up to the present the Company has not introduced its own road motor vehicles for transporting passengers and goods over short distances, it has, as an experiment, made an agreement with a contractor in Dakar to convey railway passengers, who live at some distance, to and from the station. It has also considered co-operation, for mutual benefit, with private undertakings over certain sections of the line (Bamako-Kouli-koro-Kati, etc.).

2. *Rating measures.*

a) *Passengers.* — Apart from reducing 3rd-class tickets from 0.27 to 0.20 franc per passenger-kilometre, the Railway, proceeding by stages, first of all introduced 4th-class coaches in certain trains between Thiès and Bamako. As this step was successful, it was extended, on the 5th May 1933 to the whole of the system when the Thiès-Niger and Dakar-St. Louis lines were amalgamated. At the present time, there are 4th-class coaches on all passenger trains (except the express and semi-express trains), including goods trains.

The basic rate of 4th-class tickets is about 0.14 franc.

Near important villages or groups of villages, halts have been made on the running lines, where passengers without luggage can alight or entrain.

Specially reduced rates, known as suburban rates (0.11 franc per km.), have been introduced around the main centres: Dakar, Kaolack, Bamako, Diourbel.

A very liberal policy has been introduced as regards allowing passengers to take foodstuffs, and small animals with them; the Higher Authorities have been

asked to give passengers at suburban rates the right to the free carriage of 30 kgr. (66 lb.) of luggage as with the usual rates.

b) *Goods.* — In the case of goods transport, special provisional tariffs at very reduced inclusive rates have also been introduced, applicable to the products of the country and to imported goods, in order to meet road competition from and to the ports.

These tariffs include rates aplicable to consignments of 50 kgr. (110 lb.), but in order to encourage grouping, additional reductions are granted to consignments sent by complete wagon loads of a minimum of 4 tons, or paying on this weight, except in the case of light bulky goods for wich the minimum weight is lower.

Then too, the general classification of goods has been revised and the number of classes increased from 4 to 6.

The procedure for making demands for rolling stock has been simplified and the consignor, when it is a question of composite loads, is not required to give a list of the packages to be transported.

When traffic is heavy, certain halts and stations with insufficient traffic to be kept open all the year are authorised to send and receive full wagon loads.

3. *Acceleration of goods transport.*

One of the advantages short-distance road transport has over the railway is that the road hauliers are not bound by any fixed timetables and so can deliver goods in the shortest possible time and assure door to door transport.

In order to remedy the unfavourable position of the railway in this respect, careful investigations have been made into the working at the departure stations and during the journey to speed up the traffic, the regulation transit times being considered merely as maximum times which in practice should be shortened. Thus a distributing-collecting service has been set up and the practice started of sending out advice notices to enable the consignee to take delivery of his goods as soon as they arrive at their destination.

Express consignments are moreover accepted by the stations for transport within shorter periods than is laid down in the tariffs in force.

Shunting operations are carried out at night in order to speed up the running of empty and loaded wagons, and during the time of heavy traffic, provision has been made for the loading and unloading of wagons to take place at night.

* * *

The various measures enumerated above, introduced by the Railway, have already given appreciable results which it is endeavouring to increase still more. For this purpose, other measures are being investigated or put into practice. Thus the goods wagons have been altered to enable the transport of pea-nuts in bulk or in mixed loads to be carried out. Tests are being carried out in connection with the transport of fresh meat, vegetables, and fish in refrigerator vans on passenger trains, and insulated containers will be purchased shortly so that trials can be made in carrying fresh meat.

* * *

Thanks to the measures mentioned above, the passenger traffic, which was continuously decreasing during the last few years, has shown a very definite increase during the year 1933 although, short crops adversely affected export trade and quotations were very low.

This recovery has been especially noticeable since the beginning of 1934.

[621 (.43)]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION.

INQUIRY INTO QUESTIONS OF IMMEDIATE INTEREST.

(Decision taken by the Permanent Commission at its Meeting held on July 29th, 1933.)

QUESTION I.

Rail motor cars from the point of view of their construction.

A. – Types of engines. – Forms of transmissions. Running gear. – Brakes.

REPORT

(Countries outside Continental Europe),

by E. WANAMAKER,

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PART I.

General.

The internal combustion engine.

The invention and development of the internal combustion engine has probably done more to change the methods of transportation than any other discovery or invention. Man's conquest of the air and efficient utilization of highways, has been made possible by the development of this form of motive power. However, these two forms of transport, highway and airway, are yet in their infancy.

The introduction of the internal combustion engine in rail equipment and ships is today becoming an important factor. The extent of its adoption is yet to be determined, service and economy being the two factors of measurement most involved.

The development of the gasoline engine was given a tremendous impetus when the automobile was introduced. The reasons are most obvious : people instinctively desire speed and freedom of movement, manufacturers desire profit. The economic mass production and use of automobiles awakened an interest in the application of internal combustion engines in all fields requiring power.

Railway operators were quick to learn that the severe demands peculiar to their service required a special type of engine. Manufacturers, due to the very slight opportunity for sales in this field, were not interested. Steam power was giving good service and meeting all demands made upon it.

It was not until the development of highways and highway motors reached a stage, wherein their use began to have an undesirable effect upon railway business, by offering a form of competition which it seemed could not be met solely by steam, that serious consideration was given to the development of internal combustion engines for rail service. Since that time progress has been quite rapid — necessity, the mother of invention — engine builders and manufacturers of electrical rail equipment cooperating with the railway companies.

The primary and essential require-

ments of rail motor engines are light weight, small space requirements, simplicity, ruggedness, and reliability.

Rotative speeds must be suitable for good engine performance and at the same time satisfactory as regards the type of transmission used. The proportionate relationship of the various parts must be carefully worked out and co-ordinated, especially so since there should not be permitted a single pound of idle or excess weight.

Gasoline engines, some of them burning distillate, up to and including 600 horse power capacity are in successful operation.

Among them are included the following which are typical :

Horse power.	Number of cylinders.	Bore and stroke.	Arrangement of cylinders.	R. p. m.	Horse power per cylinder.
200	6	7″ × 8″	In line	1 060	33.33
275	6	7 ½″ × 8 ½″	»	1 060	45.83
300	6	8″ × 10″	»	900	50.00
400	8	8″ × 10″	»	900	50.00
600	12	7 ½″ × 8 ½″	Vee	1 200	50.00

The more recent of these are quite rugged and a decided improvement over the earlier type.

Crankshafts are more liberally designed, likewise all other parts. Aluminum heads and alloy pistons have contributed much to the improvement as has multiple spark plug, battery ignition.

Quite a number have been equipped with suitable carburetors for burning distillate; however, the recent developments in the rail type diesel are such that in all probability the large majority of engines purchased in the future will be of this type, gasoline engines being purchased only where the equipment is of comparatively small capacity, or is to be unfrequently operated.

Recently, there has been built by the Winton Engine Corporation several 600-H.P. high-compression 2-cycle single acting diesels with eight in line 8″ × 10″ cylinders turning at 750 r.p.m.

This airless injection engine has exhaust valves and is ported for scavenging and supercharging air.

They have built and placed in operation one 900-H.P., and are now building several of them; also some 1 200 H.P. as herein listed.

Horse power.	Number of cylinders.	Bore and stroke.	Arrangement of cylinders.	R. p. m.	Horse power per cylinder.
600	8	8″ × 10″	In line	750	75.00
900	12	8″ × 10″	Vee	750	75.00
1 200	16	8″ × 10″	»	750	75.00

The foregoing are typical of this general type.

For power unit or locomotive service, it is proposed to dual the 600, 900, or 1 200-H.P. engines, and the designs have been completed for a 3 600-H.P. locomotive made up of two dual 900-H.P. engine units, each unit of which may be operated separately as an 1 800-H.P. unit if desired. A design has also been completed for a fully articulated 3 600-H.P. job.

The Busch-Sulzer Company built and have been testing in their plant for the last several months a 1 600-H.P., 550-600 r.p.m. engine, 2-cycle single acting Vee-type, with eight 13 1/2″ × 16″ cylinders.

This engine may be built with 10-12-14 or 16 cylinders, with a maximum rating of 3 500-H.P. capacity. This airless injection engine is ported for exhaust scavenging and supercharging, with long trunk type pistons and sludge chamber between crank case and combustion chambers.

Fairbanks Morse & Company have built and are testing a 300-H.P. opposed piston 2-cycle single acting, airless injection, 1 200 r.p.m. vertical 6-cylinder (12 pistons), engine, ported for exhaust scavenging and supercharging. The upper crankshaft drives the auxiliaries and is connected to the lower by silent chain.

They propose to use this typical design in building engines as herafter tabulated, and are at the present time completing a 1 200-H.P. engine.

Size of locomotive, car or power unit.	Number of engines.	R. p. m.	Individual engines.			
			H. P.	Cylinders.	Bore.	Stroke.
300 to 800	1 to 2	1 200	300	6	5″	6″
			400	8	5″	6″
500 to 1 400	1 to 2	900	500	6	6 ½″	8″
			700	8	6 ½″	8″
750 to 4 800	1 to 4	720	750	6	8″	10″
			1 000	8	8″	10″
			1 200	—	—	—
1 800 to 4 800	1 to 2	500	1 800	6	12″	15″
			2 400	8	12″	15″

These diesel engines, like most of the engines built during the past two years, range in weight from twenty to twenty-five pounds per horse power; however the Westinghouse Co. has built some 265-H.P. 4-cylinder in line — 400-H.P. 6-cylinder in line — 500-H.P. 8-cylinder Vee-type, and 800-H.P. 12 cylinder Vee-type, 4-cycle single acting airless injection 900 r.p.m. engines, all with 9″ × 12″ cylinders ranging from 30 pounds weight per horsepower for the largest to 40 pounds per horsepower for the smallest.

Also the McIntosh and Seymour Co. have built for the American Locomotive Company some 300-H.P. six 9 1/2″ × 10 1/2″ in line cylinders and some 600 H.P. six 12 1/2″ × 13″ in line cylinders, 4-cycle single acting airless injection 700 r.p.m. engines for switching service, with a somewhat heavy weight per horsepower.

The De Le Vergne Company has built some 200 and 300-H.P. 4-cycle, single acting airless injection, 6 cylinder in line, 720 r.p.m. engines for the Baldwin Locomotive Company and are now designing some larger engines.

The Baldwin Company has also arranged for handling the M.A.N. engine made in Germany.

The Allis Chalmers Mfg. Co., in cooperation with the Hooven Owens Rentschler Company, have recently completed and are testing a 1 400-H.P. 700 r.p.m. engine weighing 14 pounds per horsepower; the details of design, however, have not yet been made public.

The Ingersoll Rand Co. has built and has in operation on several railroads several single 300-H.P. and several dual

300-H.P. power plants in locomotives and motor cars. These engines are 4-cycle, single acting, airless injection six cylinders in line 550-r.p.m., of fairly heavy construction and are typical of this design. They have also built one larger engine for a switching locomotive.

The Cummins Engine Co., have built light-weight diesel engines of small capacity for truck and industrial service and have placed some in light rail switching units. This type of engine has low-pressure fuel control with pre-heated fuel charge. The builders hope to adapt it to light rail service.

There are several other manufacturers who are experimenting and developing diesel engines for rail service, all of which indicates progress along the lines of rail motorization.

When considering internal combustion engines for any rail service, it is advisable to give consideration to their use in all classes of rail service, since the principles involved in the design, maintenance and operation of this new type of motive power for railways are to all commercial intent practically the same whether for use in light weight high speed trains, heavy trains, or switching service.

Transmission and control.

There have been used three general types of transmission between the engine and the driving wheels of rail motor equipment : Mechanical, Electrical, Hydraulic.

In the United States, mechanical transmissions have not been generally successful in capacities greater than one hundred and fifty horsepower in heavy duty service.

The transmissions have generally been of the selective gear and clutch type — various types of clutch facings have been used, generally of the dry type, although a few prefer discs with cork inserts running in oil.

One manufacturer of light switchers has stated that they are now testing a new design which they hope will successfully transit five hundred horsepower.

Several manufacturers are working on the design and development of mechanical transmissions in the hope that eventually a satisfactory design will be evolved — one that will render a service performance equal to that of the electrical transmission, and at lower first and maintenance costs.

The flexible drive necessary between the engine and the driving axle seems to offer a serious problem for larger power.

The electrical transmission consisting of generator and traction motor or motors, together with a suitable control, is such that there is no direct mechanical connection between the engine and the driving axle, thus affording what amounts to a one-hundred per cent cushion between the engine, the driving axle and the rail. An infinite range of economic speeds is inherent in this type of transmission the advantages of which are plainly obvious from an operating standpoint.

There are two types of electric transmission in use generally known as « Differential Field Control » and « Automatic Field Resistance Control ». The majority now in service are of the differential type, primarily due to its simplicity; in some cases, however, it was felt that the added complication of the automatic field resistance control was justified by a limited increased efficiency.

To date all of the electric transmissions in commercial service utilize direct current generators and motors generally at voltages not in excess of 750 volts. These transmissions are very reliable and comparatively low in maintenance costs; however, their first cost and weight are greater than the other forms of transmission.

Research and investigations now under way indicate that the disadvantages of high first cost and weight ratio may

be eventually overcome by use of higher direct-current voltages or utilization of alternating current. Or possibly by the utilization of vacuum tubes in connection with either direct or alternating current, or in connection with a combination of the two. Inasmuch as the generator and motor of a rail motor transmission is isolated from all other electric power generating and power using systems or units, it is probable that a high frequency could be advantageously employed.

The storage battery as an integral and essential part of an electric transmission should be of a very rugged type of construction, and should be provided with an efficient regulating and protective control. Unfortunately this provision was not made on most of the rail motor equipment now in operation.

The hydraulic transmissions tried out in rail service so far, in the United States, have not been commercially successful. Several manufacturers are endeavoring to develop hydraulic transmissions which will meet the severe demands peculiar to rail service.

Rail motor car construction.

The first rail motor car to be operated with fair success in commercial service on a railway in the United States was designed and built by W. R. McKeen for the Union Pacific Railroad in 1908.

During the few years immediately following, the McKeen Motor Car Company built some 150 odd cars of similar design for various railroads. The Union Pacific still has some of these cars in operation.

The car body was of a steel shell design with center entrances. Extremely light center sills were used, depending largely on the outer shell for strength and rigidity. The forward end was of a sharp wedge shape, the rear being rounded. The 4-cycle gasoline engine was of the 6-cylinder slow-speed reversible type. According to the method of rating in effect at that time, the engine was of 175 horsepower capacity; as rated today, it was probably 150 horsepower capacity.

It was mounted on the 4-wheel forward truck with a chain drive between the transmission and driving axle. The two driving wheels were of considerably larger diameter than the trailing pair.

The vertical engine extended upward through an opening in the car floor into the operator's cabin in such a manner as to permit the operator to from time to time look at the ignition, carburetor, valve mechanism, etc. Fin radiation was installed in the pilot and in the car body, that in the body being used for heating during cold weather periods.

The engine was started by air. The air for same and for brakes was supplied by a small gasoline-engine driven-compressor and a compressor driven directly by the main engine. Gasoline vapor lights were used at first. The transmission had two speeds. The engine had no crankcase, the oil being used but once.

Most of the cars were 70 feet long overall and weighed 40 tons.

In 1910, the General Electric Company built the first gas-electric motor car to be operated in the United States.

This car had a steel body built along conventional lines in vogue at that time, but of lighter construction; later some were built with center entrances. The forward end of the car was roundly pointed. The length of the car was approximately 70 feet and its total weight 49 tons.

The power plant was located in the forward compartment and consisted of an 8-cylinder 4-cycle Vee-type 550 r.p.m. gasoline engine, direct connected to a 600-volt direct-current generator which, through a drum controller, supplied current to two traction motors mounted in the forward truck.

The engine was started by air and controlled by hand throttle in connection with manual control of the generator field resistance.

A separate gasoline engine combined with an air pump furnished the initial air supply for starting the main engine; there was also a small compressor driven directly by the main engine. This engine also operated a small 110-volt direct-current generator for lighting the car. The engine cooling radiators were placed on the roof. The car was heated with a coal-fired hot water heater; in some cases railway mail compartments for sorting mail en route were provided.

Some 95 cars of this type were built for various railroads, some of which are still in service.

The performances of these cars were very successful on the slow-speed local schedules in effect up to within the last few years. It was from this design that the present gas-electric motor cars were developed.

There was but little change in the general design of motor car construction until the recent advent of the light-weight streamlined motor car or motor train, except that the storage battery was incorporated into the power plant to accelerate excitation and to supply current for lights etc., the introduction of electric motor-driven air compressors, for high-speed air brakes, of forced fan engine water cooling, of inherent or automatic generator control, and of anti-friction bearings.

In addition, the introduction of remote control made possible double-end operation (that is from either end of the car).

At first the motor cars were operated singly, but with the increase of power plant capacity trailers were designed and operated in connection with them as passenger motor trains.

The increase in capacity also made it possible for the larger cars to be used in mixed and local freight train service.

* * *

The « Zephyr », recently completed by the Chicago Burlington and Quincy Railroad, and the Union Pacific, M-10000, new aluminum trains, as hereinafter described are typical of the newest type of rail motor passenger train, that is streamlined, light-weight, articulated, high-speed trains with a low center of gravity.

The *Chicago Burlington and Quincy* train was built by the Edward G. Budd Manufacturing Company at Philadelphia. The train consists of three car bodies carried on four trucks. It is 196 ft. in length and it weighs 195 000 lb. There are seats for 72 passengers in the second and third cars and space is provided in the first and second cars for 50 000 lb. of baggage and express. The first car also contains a 30-foot mail compartment. The passenger accommodations are divided among three compartments. At the rear end of the second car is a 16-foot smoking compartment with seats for 20 persons. At the front of the third car is a 31-foot compartment with seats for 40 persons, and at the rear of this car is a solarium-lounge with chairs for 12. Side doors and steps are provided for passengers in the two rear cars. In the second car the entrance is between the smoking compartment and the buffet adjoining the baggage compartment. In the rear car the entrance is at the rear of the main passenger compartment.

The car body structure.

In its structure this train is a complete departure from conventional design. To a very large extent the entire body structure from floor to roof performs load-carrying functions. The characteristic truss form of construction adapted by the Budd Company for the utilization of built-up sections of thin-gage Shotweld stainless steel is used.

The Shotweld process, developed and patented by the Edward G. Budd Manufacturing Company, effects a specific regulation of the pressure, the electric current value and the duration

of its flow, thus maintaining unimpaired the strength and corrosion-resisting properties of the material. The welds develop a shearing strength of 75 000 lb. per sq. inch and will withstand torsion up to 90° before rupture. All welding in the structure of the Burlington train was done by this process.

Among the special features in the structure which are of particular interest are the engine bed and the method of tying the articulation castings into the framing of the coach bodies. The engine bed, fabricated by Lukenweld, Inc., is a rigid arc-welded structure of steel plate, annealed after completion of the welding. It forms a combination bumper, engine bed and bolster and is 25 ft. 3 1/2 in. long, by 8 ft. 8 in. wide. The material is Lukens Steel Company Cromansil, an alloy of chromium, manganese and silica, with a tensile strength of 90 000 lb. and an elastic limit of 70 000 lb., possessing a high resistance to fatigue and shock. The completed structure weighs 6 070 lb. It is built into the lower chord member of the side trusses and forms the foundation for the nose structure of the car.

The power plant.

The power plant for driving the train, including power auxiliaries, was designed by the Winton Engine Corporation, a subsidiary of the General Motors Corporation. The main generator, exciter, auxiliary generator and traction motors were built by the General Electric Company.

Power for propulsion of the train originates in a Winton 600-H.P. high-compression, two-cycle, 8-inch by 10-inch eight-in-line diesel engine. Power for all auxiliaries, whether driven directly or indirectly, is taken from the engine in excess of its rated output of 600 H.P. at 750 r.p.m.

Incorporated in this engine are several novel features of construction and design. For example, engine weight has been reduced to about 22 lb. per H.P. by the Lukenweld process for welding steel plate to form a single-piece engine block, comprising the crankcase and cylinder block, to which a light oil pan is attached. A nine-bearing crankshaft is carried on main bearing seats fastened to the end of individual cross members cut to form frames for the fabricated engine block. In this manner combustion stresses are transmitted directly to the bearing seats, through the solid frames held rigid by the various patterns of welded plate, which incidentally form the air-intake passages, top and bottom of the cylinder block, webbing, etc. Steel-backed, lead-bronze-faced main bearing liners, 6 1/2 inches in diameter, are clamped by shimless bearing caps held in place with jack screws acting against the frame arch below the cylinder block.

Water-jacketed cylinder liners of heat-treated cast iron are bolted to the cylinder heads, which in turn are fastened in the usual manner to the cylinder block. About mid-length are cast twenty-four oblique air-intake ports circling each cylinder liner. Thus, the cylinder block forms an air-intake manifold in which pressure is maintained by a three-lobed twin-rotor scavenging blower or compressor, mounted on the front end of the engine block. This arrangement of air intake and the use of four exhaust valves per cylinder insures scavenging of the cylinder at a minimum blower pressure. The heads of the aluminum alloy pistons are cooled by a stream of oil emitted from the top of special I-section connecting rods fitted with bearing liners having a 6-inch bore.

The possibilities in power economy, afforded by streamlining railroad equipment, required the remodeling of the conventional engine-cooling and exhaust systems to provide a smooth roof line. To accomplish this the exhaust manifold was lowered into a drop section in the car roof and the customary roof radia-

tors regrouped to form two long sections suspended from the roof inside the engine room. Heretofore, with the roof-type radiators air circulation through the radiators was furnished by the motion of the train, while with the new system of inside mounting an artificial breeze was needed for cooling purposes. Two large engine-driven fans are mounted above the partition separating the engine room from the control cab. A grilled opening in the front of the train admits air to the fans via a duct formed by the cab ceiling and the car roof. The large volume of air brought into the engine room passes through the cooling radiators and thence outside through a central longitudinal slot in the roof. This assures a minimum disturbance of the air stream at the head end of the train and insures a thoroughly ventilated engine room.

The main generator is a single-bearing, differentially wound machine placed forward of the engine and directly connected through a flexible steel-disc coupling. A direct-connected exciter is used for generator excitation purposes to give inherently the generator characteristic which permits full engine utilization over a wide range of train speed. A shaft extension is provided at the exciter end of the main generator to drive through V-belts a 25-kw. auxiliary generator mounted above the main generator. The opposite end of the auxiliary generator shaft is also extended for V-belt connections to the two fans which draw air into the engine room.

The two traction motors are mounted on the front truck of the leading car. They are series-wound motors of General Electric manufacture, having axle-bearing linings suitable for a 7 1/2-inch axle and a double nose for spring support on the truck bolster. The gearing is single reduction with a 25-tooth pinion and a 52-tooth gear. The armatures have SKF roller bearings and the axle bearings are of the sleeve type.

The traction motors are self-ventilated by multiple fans mounted at the pinion ends of the armatures. Ventilating air is taken from the engine room through canvas ducts, and motor ventilation is aided by the slight positive air pressure — about 1 inch of water — in the engine room.

Motor control consists essentially of one master controller, electro-pneumatically operated motor contactors, and reverser, together with the necessary auxiliary magnetic contactors, switches, relays, etc. The control provides for operation from the front of the train only and for starting and stopping the engine, regulating headlights, cab lights, etc. The traction motors are progressively connected in series, parallel and parallel-shunted-field combinations with transfer from one connection to the next higher effected manually.

The 25-kw. two-bearing 76-volt auxiliary generator is of the four-pole direct-current commutating-pole type. The output of the generator is furnished to the air compressors, the air-conditioning equipment, motor for train heating boiler, battery charging, lights, control, buffet ustensils, etc., at a constant voltage regardless of load, over a range of engine speed from idling to full speed, including engine regulation. This has been made possible by the combined effect of inherent regulation and the use of a new dynamic relay.

The storage battery in an Exide Ironclad 32-cell, 64-volt battery rated at 450 amp.-hr. at the 10-hour discharge rate, which is placed in a stainless-steel battery pit in the engine room. The weight of the battery is 3 260 lb. Ventilating scoops are used to increase air circulation in the battery box. The battery is used for engine cranking in addition to supplying power to the auxiliary circuits.

Two General Electric 25-cu. foot air compressors, driven by 76-volt motors, furnish the necessary air for the train.

These compressors are of standard design, but with aluminum frame parts to obtain a light-weight equipment.

The trucks.

The four trucks are all of conventional outside bearing type of construction. All have cast-steel frames and bolsters, furnished by the General Steel Castings Corporation. Their combined weight is 55 000 lb. without the motors and gears in the power truck. The power truck, in which are mounted the two traction motors, has 36-inch wheels. This is the front truck and carries the weight of the power plant. The trailer trucks, although of the same general type, are considerably lighter in construction and run on 30-inch wheels. All journals are fitted with Timken roller bearings. The axles are hollow-bored to reduce weight.

Of particular interest in the construction of the trucks is the extensive use of rubber insulation to prevent the transmission of sound and other high-frequency vibrations to the car bodies. There are inserts under the center plate, in both top and bottom equalizer spring seats and between the ends of the equalizers and journal boxes. Rubber liners in the pedestals are faced with Oilite metal plates, vulcanized on, which serve as bearing surfaces for the faces and flanges of the boxes. The bolster pads, which insulate the bolster from the truck frame, are also faced with Oilite metal. In addition to the pad under the center-plate, rubber thimbles are provided around the king pin and the center-plate bolts, the latter also including washers. A further precaution against unnecessary noise is the provision of automotive brake lining wherever the members of the truck brake rigging are likely to rub. To dampen vibrations of lower frequency, Holland helical-volute springs are used on the equalizers of all four trucks. These springs consist of the conventional helical outer coil with an inner volute spring in place of the inner helical coil. The center plate bearing, the bearing between the articulation castings and side bearings are all faced with Oilite.

No two of the trucks carry the same load. With the train normally loaded the power truck is estimated to carry a weight at the rails of 98 000 lb.; the first trailer truck, between the first and second car bodies, 67 000 lb.; the second trailer truck, between the second and third car bodies, 45 000 lb., and the third trailer truck, at the rear end of the train, 30 000 lb. The nominal journal sizes are, respectively : Power truck, 6 inches by 11 inches; first trailer, 5 1/2 inches by 10 inches; second trailer, 5 inches by 9 inches; third trailer, 4 1/4 inches by 8 inches.

Brakes.

The train is fitted with Westinghouse SME-3 brake equipment, which has been modified specifically for high-speed articulated train units. This is a straight-air system with emergency feature and also has a brake pipe which permits standard automatic operation of the brakes in case it should be necessary or desirable to move this train in connection with steam-train equipment. There are three air lines on the train :

1. The emergency pipe through which the supply reservoirs for each vehicle are charged at all times under normal operation and the loss of pressure from which causes the control valves to effect an emergency application of the brakes.

2. The straight-air pipe, pressure variations in which cause the control valves to effect graduated service application and release, and

3. The brake pipe by means of which automatic operation of the brakes can be effected when the articulated train is moving in connection with steam-train equipment or when backing up

and on which the conductor's valve in the rear car is placed.

The brake valve operates the brakes by controlling the pressure in the straight-air pipe. It is self-lapping, the degree of service application varying with the position of the handle, a feature by which great sensitivity is attained. The dead-man control is operated either pneumatically by a foot pedal or electro-pneumatically by a push-button on the brake-valve handle. The release of both of these automatically cuts off the power and causes an emergency application of the brakes. The brake valve also provides, electro-pneumatically, for an emergency application of the brakes should a failure of pressure in the straight-air pipe prevent a response to a movement of the brake valve to service application position within a predetermined time interval.

In order to effect the high rates of retardation required to keep stopping distances from speeds of 100 or more miles per hour within present limits, the brake system is designed for a 200 % braking ratio at 100 lb. cylinder pressure. Because of the increasing coefficient of brake-shoe friction as the speed is reduced, the brake-cylinder pressure is controlled automatically as the train slows down by a retardation controller, a pendulum inertia device by which brake-cylinder pressure is reduced at a rate sufficient to maintain a constant predetermined retardation rate. The retardation controller is wired in the battery circuit to solenoids on the control valves and through these the control of brake-cylinder pressure is effected.

Aluminum has been used extensively in the air-brake equipment in the interest of weight reduction. This includes the control valves and brake cylinders, etc. The supply reservoirs are of stainless steel.

The heating system.

The train is equipped with steam heating throughout. Each passenger compartment also has its own mechanical air-conditioning system. These are interlocked with the heating system so that the force-ventilation feature of the air-conditioning equipment is available both winter and summer.

Steam for heating is provided by an oil-fired Peter Smith boiler with an evaporative capacity of 500 lb. per hour at a pressure of 85 lb., furnished by the Vapor Car Heating Company. This boiler is located at the rear end of the baggage room in the second car. Its operation is completely automatic and, in order to reduce weight, the condensate from the radiators is returned to the 50-gallon feedwater storage tank. Storage is provided for 75 gallons of fuel oil.

The operation of the boiler is subject to three controls :

1. A water-level control.
2. A low-water control, and
3. A burner load control.

The water-level and low-water controls are of the electrode, commonly called spark-plug, type. The electrodes are inserted in a container or bottle which is connected to the boiler in the same manner as a water column. They are of three lengths. The lower end of the longest one corresponds to low-water level and the vertical distance between the other two marks the variation in water level within which the feed pump is controlled. Current at 110 volts, furnished by a small motor-generator set, passes from the electrodes to their grounded metal container through the water. If the water drops below the end of the longest electrode, the failure of the current acts to close the oil-supply valve and stop the burner motor. A variation of the water between the ends of the intermediate and short electrodes serves to cut the feed pump in or out.

If pressure in the boiler builds up beyond a predetermined point owing to a load insufficient to utilize all of the

steam being produced, a pressure switch operates automatically to reduce the flow of oil to the burner and the speed of the burner motor, thus maintaining a flame which is little more than a pilot light until such time as the reduction in pressure restores the flow of oil and the speed of the motor fan to their full load amount.

Heat is supplied to the passenger compartments from two sources. A fin-tube coil in the evaporator unit of the air-conditioning system in each compartment supplies heat to the fresh and recirculated air passing through the units to the compartments. Steam is also supplied to a copper fin-pipe along the truss plank near the floor on each side of the compartment. The admission of steam to both radiators is controlled by motorized valves which are actuated by independent thermostats. A thermostat for the control of the air-conditioner radiators is located on a deadlight panel near the center of each compartment about 5 feet above the floor. The thermostat for the sidewall radiators is placed near the floor and serves to bring these radiators into action automatically when the heat distribution from the air-conditioning unit is not sufficient to maintain a predetermined temperature at the floor.

A unique scheme has been developed for returning condensate from the radiators of the front and rear cars to the feedwater storage tank on the second car. Water from the radiator traps drains into small sumps, one on each of the two cars. As the water level rises in the sump, a float causes a relay to open a solenoid valve in the brake pipe, admitting air to the sump under regulated pressure and forcing the condensate through a separate return line to the storage tank. During layover periods the entire train can be heated by steam from the terminal supply. The heating and thermostatic controls are the product of the Vapor Car Heating Company.

Air conditioning.

Each of the three passenger compartments is served by a complete York mechanical air-conditioning unit of 1 1/2 tons nominal capacity. The compressors as well as the condenser and evaporator units are all located within the underbody below the floors of the coaches. The evaporators deliver air through the grilles in the bulkheads over the center doors into the compartments. Recirculated air leaves the compartments through filter-protected openings in the floor over the evaporator units.

The motors for operating the compressors and the evaporator unit fans were manufactured by the General Electric Company. A 7 1/2-H.P. A.C.-D.C. motor operates the two compressors and the condenser fans on the third car and a 3-H.P. D.C. motor drives the compressor unit and the condenser fan on the second car. For standby service when the main power plant is not in operation a tap from a 220-volt, 60-cycle terminal supply can be plugged in to operate the A.C. motor on the rear coach. This drives the two units on this coach and the D.C. motor becomes a generator which supplies current for reduced-capacity operation of the unit on the second car. The D.C. motors operate on 76-volt current from the head-end supply. Two 1/4-H.P. and one 1/3-H.P. motors drive the evaporator fans.

The entire air-conditioning equipment has been designed with the requirement for light weight as a major objective. The evaporator units, including both steam and refrigerating fin coils, are aluminum. The compressor motors operate at 1 750 r.p.m. The complete equipment, including the motors and controls, has a total weight of about 2 400 lb., and with refrigeration lines, water lines, electric cables, etc., included, does not exceed 3 000 lb.

Copper pipe with sweated fittings has been used throughout the train for water,

steam and air. Its use has effected a piping weight reduction estimated at 60 %. It is scale-proof and once installed possesses a high degree of permanence. Because of the difficulty of access for replacement of some of the piping on the Burlington train, this factor was of considerable importance. Except for a few special fittings, no iron or steel pipe has been used.

Lights.

The front headlight is a 14-inch 250-watt, Golden Glow unit made by the Electric Service Supplies Company. The back-up light is a 9-inch, 40-watt unit made by the same manufacturer. The marker and classification lights are Pyle-National airplane-wing lights in housings made by the Budd Company. These lights are all built into the body of the train.

All lights inside the car and also all auxiliary apparatus are controlled through Westinghouse Nofuze load centers. Arrow, Hart & Hegeman heater switches provide for connecting inside lights all in multiple, for using only alternate lights and for dimming the lights by connecting the two groups in series.

This train has for several months made exhibition tours over various railroads and was exhibited at the Century of Progress, Chicago.

It will be placed in regular revenue service between Lincoln, Omaha and Kansas City, operated on a schedule of 62.75 miles per hour.

* * *

The Union Pacific train was built by the Pullman Car & Manufacturing Company, at Chicago. The high-speed light weight three-car passenger train consists of a forward car, 72 ft. 8 in. long, containing the power plant, a 33-foot mail compartment and a small baggage room; a second car, 59 ft .10-in. long, which is a coach seating 60 passengers; and a rear car, 71 ft. 11 in. long, which is a coach seating 56 passengers, with a buffet at the rear for serving light meals to passengers at their seats. The train is articulated, the three cars being carried on four trucks. The total weight of the train is 170 000 lb., about half of this weight being carried on the forward or power truck.

The cars are about 8 inches narrower and the car roofs 3 inches lower than in conventional car design, and this substantially reduced cross-sectional area, in conjunction with light-weight and streamlined design, reduces train resistance to a relatively low value. It is expected that the 600-H.P. 12-cylinder distillate-burning engine, with its electric transmission, will develop a balanced speed of 90 m.p.h. on tangent level track and be capable, under favorable conditions, of a maximum speed of 110 m.p.h.

Car design and construction.

To obtain the desired light weight of cars, it was necessary to choose between the aluminum alloys and stainless steel as material for fabricating the cars. The former was decided upon because of the possibility of using extruded metal shapes to take the place of ordinary rolled shapes and pressings, and because aluminum plates can be readily formed for the curved surfaces required by streamlining. The streamlining used was worked out with the aid of wind tunnel tests on models, and consisted essentially of giving the cars a special shape, shrouding the trucks, providing shields to cover gaps between cars and setting windows and doors flush with the outer surface of the cars.

The cars are tubular in section with the outer surfaces of aluminum sheets and framework built up of extruded aluminum alloy sections. All of the metal in the framing is co-ordinated to act

as a unit, whether for draft or buff, as it is impossible to deflect or stress any member without having adjacent members bear their portion of the strain. This differs from the ordinary form of car design, in which draft of buffing shocks are taken care of by longitudinal underframe members. To provide for the hazard of grade-crossing collisions with highway vehicles, the nose of the front car is built out from the heavy engine base in the form of structural members which make a strong parabolic arch.

To provide both heat and sound insulation, the entire train is insulated with two inches of Rokflos. The floors are aluminum alloy plates covered with Magnesite, a composition flooring, and cork tile. Duplate shatterproof glass is used for the windows, which, in addition to its non-shattering qualities, keeps out sunlight glare by excluding a part of the light frequencies in the solar spectrum.

The interior of the car is blue, shading down from nearly white at the top to a dark blue color between the window sills, which are made of Micarta.

Trucks are rubber cushioned.

All of the four trucks are of the four-wheel type with cast-steel frames and rolled-steel wheels. The front or power truck has 36-inch wheels equipped with S K F roller-bearing journals, placed outside of the wheels, to provide space necessary for the two motors geared one to each axle. The armature shafts are also on roller bearings, the armature being wound for a safe maximum speed of 110 m.p.h. The traction motors are G.E. type 716-B-1 600-volt D.C. motors, rated at 300 H.P. They are force-ventilated, the air being cleaned before it is passed to the motors. The remaining three trucks have 33-inch rolled-steel wheels and inside-type roller-bearing journals to reduce the truck width and minimize air resistance.

There is no metallic contact between journal boxes and truck frames, these being separated by rubber. The rubber separation is paralleled by coil springs which take the static load. Extreme lateral motion of the trucks is damped by rubber bushings, and chafing plates, ordinarily used between the truck bolster and transom, have rubber packing to cushion the movement due to acceleration and deceleration. All coil springs are mounted on rubber pads.

Automatic brake control.

The power truck is fitted with clasp brakes, while single-shoe wheel brakes are used on the trailing trucks. Compressed air for the brakes is supplied by two G.E. air compressors, each having a capacity of 25 cu.ft.p.m., driven by Louis Allis motors. To avoid rearrangement of the signaling system and also to avoid any additional operating hazard it is necessary to stop the train from 100 m.p.h. in the same distance as a conventional steam train can be stopped at ordinary speeds. To provide the necessary uniform rate of retardation, a new brake control called a « decelerometer » is used. This device consists essentially of a movable weight of about 100 lb., sensitively mounted on ball-bearing rollers, and arranged to move in the line of motion of the train, suitably restrained by a calibrated spring. Motion of this weight controls brake cylinder pressure in proportion to its inertia, and therefore in proportion to the retardation of the train. To avoid a jolt at the moment of stopping the decelerometer is provided with a valve device which changes the rate of deceleration from a fixed to a low value just before stopping.

The brake system is provided with two air lines, one of which distributes the air to the reservoirs under each car, and the other is used to control pressure in the brake cylinders. Parallel to this pneumatic circuit is an elec-

tric circuit actuated by contact points on the brake valve, which operates a magnetic control on each pneumatic relay valve. This not only synchronizes, but also accelerates all brake applications and releases.

Power plant.

The power plant consists of a 12-cylinder, V-type distillate-burning Winton engine rated 600 H.P. at 1 200 r.p.m., directly connected to a 425-kw. Westinghouse generator. The generator is equipped with a built-in exciter, and the characteristics of the exciter, generator, motor and control are such that the load on the engine is constant at any car speed, being governed entirely by the position of the engine throttle.

A 25-kw. auxiliary generator of Winton design, driven from the end of the main generator shaft, is used for charging the storage battery and operation of air compressors, lighting, air-conditioning equipment and other auxiliaries. The voltage of this generator is constant at all speeds, including idling. A 64-volt Exide Ironclad MVAH-17 battery is floated across the auxiliary generator. It serves the requirements of lighting and auxiliary circuits when the main engine is not in operation.

There is a 7 1/2-kw., 76-volt, 1 200 r.p.m. D.C. generator driven by a Waukesha gasoline engine, in the baggage compartment of the leading car. At the present time, this engine-generator set is used only for emergency lighting and for heating purposes during yard layovers in winter. It can, if required, also be used for battery charging. If it is decided that the train will always be operated as a 3-car unit, as it is at present, it is probable that this engine generator set will be removed. However, if it is decided that a sleeping car is to be added to the train, the engine-generator set will be retained to furnish power for the compressor and condenser fans in the cooling system, since the 25-kw. auxiliary generator would not, in this case, have sufficient capacity to handle the additional load.

On the meter panel in the engineman's cab are the following meters and gages : D.C. voltmeter 0-1 000 volts; D.C. ammeter, minus 200 to plus 200 amperes; speedometer, 0-120 m.p.h.; thermometer, 32-212° F.; oil gage; fuel gage; engine tachometer, 0-1 300 r.p.m.; air brake pressure gage; two d.p.d.t. knife switches for reversing ignition polarity. Westinghouse canopy — type TM 359 switches are used for controlling headlights, gage lights, engine starting circuits, ignition, etc., and type TM 13A switches control distillate pumps, air pumps, gas pumps and exciter field.

Heating and air conditioning.

An air duct is carried throughout the train on each side below the floor line, and there is also a central ceiling duct, these ducts being connected between the cars by flexible bellows. Heat is obtained by passing air through the radiators of the engine, this air being forced by blowers through the floor ducts, there being an outlet at each seat. Air is exhausted through openings in the ceiling duct. Two oil-fired, hot-air furnaces, supplied by the Vapor Car Heating & Lighting Company, are installed in the baggage compartment. They are used to heat the cars at terminals and in the yards when the engine is not running, and can also be used for emergency, should there be a failure of the heat from the engine radiator. These furnaces are provided with motor-driven pumps and fans and electric ignition. The burners are designed to operate with either D.C. or A.C. power and, in the former case, have windings which generate A.C. current, stepped up by a transformer to approximately 10 000 volts for ignition purposes. Thermostats control the heating in the cars by operating motorized dampers controlling the heat from the engine radiator, or by

controlling the operation of the oil burners.

Air-cooling equipment is located in the baggage room. It is an adaptation of the Pullman mechanical system, having a capacity of 7 1/2 tons. It is driven by a direct-connected Louis Allis 12-H.P. direct-current motor. For cooling the cars, the circulation of air is reversed, the cold air being discharged from the central ceiling duct and exhausted through the floor ducts. A thermostat in the second car controls the operation of this unit.

Lighting.

Indirect or cove lighting is supplied by placing lamps in a trough or a channel on either side of the central ventilating duct. The light is uniformly reflected on either side against the ceiling, providing even distribution at the reading position. Type-S 64-volt 10-watt lamps are used. They are spaced 6 inches apart, and the circuit arrangements allow for three intensities, the lowest being used for night lighting when passengers are sleeping. With all lights on, the illumination at the reading plane is about 5 foot-candles.

A special double-beam headlight, which provides both horizontal and vertical light beams, was developed for this train by the Pyle-National Company. The vertical beam will serve as a marker to herald the approach of a high-speed train from a considerable distance. The vertical light has a 10-inch silvered glass reflector, and the horizontal headlight a 12-inch reflector of the same type. Both headlights use special 75-volt lamps, the upright light having a 100-watt lamp and the forward light a 250-watt lamp. The double headlight unit, including reflectors, mountings, lamp stand, and focusing devices, is completely built in, the housing being formed as a part of the car-roof streamlining at the front end of the train.

Classification lamps ar likewise built in, the lenses being flush with the streamlining at the front end. These lamps are a modification of the Pyle-National aircraft navigation lights or wing lights. Clear, refracting-type lenses are mounted flush with the skin of the car without interference with the streamlining. While it would appear that the light beam would point off to the side of the car, the refracting-type lens directs the beam forward, the effect being the same as with a standard classification lamp. These classification lamps are equipped with 5 1/2-inch reflectors, and a movable shutter between the reflector and the lens provides for showing either white or standard green indication.

Marker lamps at the rear end are of the same design, built in flush with the streamlined skin of the car. The lenses of these lamps are standard red instead of clear, and the lamp is without the shutter mechanism, as no change of indication is required.

Cab signals.

The train is equipped with cab signals, the same as used on steam locomotives, and these signals will be operative in the territory equipped for cab signaling extending between North Platte, Neb., and Cheyenne, Wyo. The cab signaling is of the two-indication type, furnished by the Union Switch & Signal Company. The signal is mounted horizontally on the front wall near the center of the cab, so as to be within the line of vision of both the engineman and fireman (1). The cab signal has two indications. The one at the right displays a green aspect when the track ahead is clear for at least two blocks, while the one at the left displays a red-over-yellow aspect when traveling in a caution or occupied block. In addition to

(1) The fireman is supposed to qualify as a maintainer.

these visible indications, an audible signal is provided in the form of an air whistle which starts to blow when the cab signal indication changes from green to red-over-yellow, and continues to blow until the engineman operates the acknowledging switch, located on the right wall of the cab near his seat. The whistle and the magnet for the control of the whistle are mounted below and to the right of the engineman's seat.

No special equipment for shunting the track circuits is provided on this train, it being anticipated that the weight on the front truck will afford an adequate shunt together with the wheels on the six axles on the remainder of the train.

The Pullman Company has just completed for the Union Pacific a 6-car train of somewhat similar design, powered with a 900-H.P. Winton diesel engine. Sleeping accommodations are provided in three cars of this train, with many innovations including louvered sliding doors for each berth.

At the present time, two nine-car trains of somewhat similar construction are being built for the Union Pacific. Each train is to be equiped with a Winton 1 200-H.P. diesel engine.

It is expected that these trains and also two additional trains of the « Zephyr » type, now being built by the Budd Company for the Chicago Burlington and Quincy, will be ready next spring.

Several streamlined, light-weight, high-speed, diesel-powered motor trains, some articulated, and some with conventional trucks, are now being built or are in process of design for several other railroads. Included among these is a train for the New York, New Haven & Hartford, being built by the Goodyear Zeppelin Corporation, and one for the Baltimore and Ohio Railroad, being built by the American Car and Foundry Company.

Fuel.

The subject of fuel is ever an important one, being as it is, the basic foundation upon which the internal combustion engine is built. The supply of suitable fuel and its cost is therefore by far the most important factor involved in the whole subject of rail motor equipment.

The world's petroleum experts tell us that the supply is more than ample for many years to come and at a cost comparable with the prices of today.

The geologists and coal experts tell us that, in so far as diesel engines are concerned, we need have no fear of failure of an economic fuel supply, they feeling, and this opinion is shared by many scientists and engineers, that should petroleum fuel for diesels rise to an uneconomic figure, they, by collaboration with the engine builders, will be able to develop a low-cost coal-base fuel for diesel engines, provided some changes are made in the fuel injection and some other parts, the combustion chambers sealed from the crankcase, and an improved lubricating oil is used.

By an improved lubricant is meant a good petroleum-base lubricating oil to which, by processing at an economic figure, has been added the properties of being able to cling to the surface to which it has been applied in spite of heat, wash and scraping or wiping action, and which is to a large degree non sludging or non oxidizing. With the vast research and development facilities and the talent such as are available today, it is probably not unreasonable to assume that the future of the diesels is bright indeed and that their use will be greatly extended wherever power is required.

Under the « The Internal Combustion Engine » section reference is made to some of the various types which have been designed for rail service and which indicates the desirability of choosing rail equipment quite carefully when looking forward to protection of the investment. It is readily apparent that some designs seemingly offer themselves for a long

economic service life, by reason of their being adaptable to such conditions as may possibly develop. Improved lubricants have been developed and will in all probability be commercially available in the not far distant future.

The following fuel specifications are largely used for internal combustion engine rail motor cars and locomotives in the United States today.

The handling of the lighter fuels such as gasoline, both in terminals and on cars and locomotives is an exceedingly important subject on account of the fire hazard involved.

Many protective devices have been developed and, if properly installed and maintained, will greatly reduce the liability, especially so if all concerned with the operation and maintenance are carefully instructed and supervised, so that they will take every precaution at all times while performing their duties.

Some typical fuel specifications for rail motor cars.

Gasoline for rail motors.

Color (Saybolt scale)	16.
Doctor	Neg.
Corrosion test	Neg. Immersion.
Distillation range :	
Not less than	
5 % over at	180° F.
50 % over at	284° F.
90 % over at	392° F.
End point, not over	437° F.
Sulphur, not over	0.10 %.

Average A. P. I. 59.6-B 59.1.

Petroleum distillate for rail motors.

1. The distillate shall be free from water or suspended matter.
2. The doctor test shall be negative.
3. The viscosity test shall not be higher than 34 seconds Saybolt Universal at 100° F.
4. Distillation range :

5 % over at not above	375° F.
20 % » » » »	425° F.
50 % » » » »	450° F.
90 % over at not above	550° F.
End point not over	600° F.

5. At least 95 % shall be recovered after distillation.
6. The residue left in the flask after distillation shall not show an acid reaction and shall not exceed 1-1/2 %.
7. Sulphur shall not be over 0.3 %.

Average A. P. I. 39.5—B 39.2.

Fuel for oil or diesel rail motors.

The fuel oil shall be a hydro-carbon oil, free from acid, grit or other foreign matter likely to clog or injure the valves or pipe lines. It shall be free from water, sediment or suspended solids, except as hereinafter indicated.

The oil shall conform to the following requirements :

Gravity	Not heavier than 20 degrees A. P. I.
Flash	Min. 125° F.—Max. 175° F.
Viscosity, Saybolt-Universal at 70° F.	Min. 30 sec.—Max. 60 sec.
Cold test	Max. 15° F.
Water and sediment	Max. 0.10 %.
Sulphur	Max. 0.50 %.
Carbon residue (Conradson)	Max. 0.50 %.
Thermal value per gallon	Min. 135 000 B. T. U.
Distillation :	
10 % point at deg. F.	Max. 440.
90 % point at deg. F.	Max. 620.
Residue at 90% after standing 2 hours at 70 F.	Fluid.

Average A. P. I. 38.3—B 38.0.

All tests shall be made in accordance with the latest A. S. T. M. methods.

A one-quart sample will be taken preferably from the tank car, or storage tank if unavoidable.

Fuel for oil or diesel rail motors as put out by one engine builder.

The fuel oil shall have a net heat content of not less than 18 500 B. T. U. per pound.

Fuel oil shall be hydro-carbon oil which is free from grit, acid and fibrous and other foreign matters likely to clog or injure the valves.

Viscosity at 70° F. not higher than 150° Saybolt Universal.

Flash point shall not be lower than 150° F.

Sediment and water content not to exceed 1 %.

Sulphur content not to exceed 1 %.

Carbon residue (Conradson) shall not exceed 0.5 %.

Average A. P. I. 38.3—B 38.0.

Lubrication.

A diesel engine in rail service, all factors included, should have an economic and useful life of not less than twenty-five years based on some five to seven thousand hours service per year, depending upon the class of service during this period. Such performance is deemed feasible provided the engines are so designed that they will not become obsolete during this period and provided they are properly maintained and lubricated. Lubrication is a much more important factor as regards net or overall ultimate economy than seemingly has been generally realized.

Whether in high-speed long distance switching or freight service, superior lubrication is necessary to insure long life, high availability and low cost of operation, all of which are essential if the requirements of rail service are to be fully met.

Some engineers have set up 1 000 000 miles in high-speed passenger service, equivalent to approximately four years at some five to six thousand service hours per year, as the general shopping period, that is, the time at which crankshaft and other wearing parts would require refitting.

In any event, it is evident that wear should be reduced to the lowest possible minimum and, when that is done, a high degree of reliability and availability will obtain. To this end every effort should be made to obtain lubricants that in addition to possessing all the desired factors of viscosity, flash, fire, etc., shall possess the factor of being able to cling to the surface in the face of heat, washing action (water sometimes gets into the oil), scraping and wiping action and to offer high resistance to oxidation and sludging.

It should be constantly borne in mind that the high efficiency of the diesel engine has long been recognized, but that the problem of designing it to successfully meet the exacting demands of heavy-duty rail service has been a most difficult one. Light weight and small space requirements are essential, and yet the strength of the parts and the lubrication must be such as to protect and guarantee against even occasional accident to or wrecking of the engine, caused by failure of parts or lubrication, even though such happenings be very unfrequent, since the cost of repairing a wrecked railroad diesel is usually very great. The engine damage incurred by train wrecks which seem to unavoidably happen from time to time, is about all the wreck expense the diesel account can carry.

The better lubrication of gasoline engines is proportionately essential; however, the use of such equipment will in all probability be limited to small units in the future.

Several satisfactory low-cost methods of oil reclamation have been developed and are quite generally used in the United States.

All foreign matter is removed, likewise fuel and water dilution, the viscosity is controlled, and the color restored if desired. Heat, electrical or from oil or other fire, is used to drive off the light ends from the drainage; closed retorts with vapor relief are used in some instances; in others the circulation of the drainage through the still with a controlled introduction of steam during the

process is used; the filtering is accomplished by any one of the several common methods. In some processes acid is used to throw down the sludge before heating, in others, as in the steam process, no acid is used.

The reclaimed oil is at least equal to the new oil and many prefer it to the new, it seemingly having been tempered while being used in the engine and while going through the reclaiming process.

The cost varies as a rule from two to five cents per gallon of reclaimed oil, depending on the method used and the quantity of oil handled.

When the steam process is used, the by product (the light ends), is used as fuel for the reclaimer still, as a cleaning oil for cleaning engines or locomotives, and in some instances as a penetrating oil for loosening nuts, etc.

Maintenance and operation.

The late Captain Robert Dollar, successful marine operator and lumberman, was recognized as one of the world's most progressive business and transportation leaders. It was Captain Dollar who after the big war, developed the « Round the World Way Ship », a radical departure from the practices then in vogue. Asked one day, why his line had not yet extensively adopted the new type and class of propulsion machinery which promised to be quite superior to the older type then in use, he replied : « It takes far longer to teach the average operating and maintenance personnel to efficiently operate and care for new types of machinery than it does for the engineers and designers to develop the machine itself. Therefore, it is necessary for us to take into consideration, the time required to educate and train our personnel in new types and classes of machinery ».

The importance of a suitable organization, supervisors and maintainers, should not be overlooked if successful operation is to be obtained even with well designed equipment.

When we take into consideration the fact that much equipment built during the introductory and development stage of any radically new type of equipment must necessarily possess to a varying degree design errors and defects, it is imperative that every effort should be made by the management to secure competent maintainers and supervisors, or to so train those engaged in the maintenance of steam equipment that they master the art of internal combustion engine or motor maintenance. And it must be borne in mind that the underlying principles involved, especially as regards failure, causes and effects, are entirely different from those involved in steam equipment. Fits, tolerance clearances, etc., are far different from those employed in steam design.

In many instances, mechanical department heads and local mechanical officers thoroughly competent as regards steam equipment have failed, either by inclination or by their lack of sufficient study, to master the principles and details involved in this new type of equipment; hence a failure of such equipment under their supervision and direction to render a good and economic service which may result in condemnation of the equipment. Others have mastered the subject or assigned full authority over their rail motor equipment to a competent staff officer, with the result that the equipment under their supervision and direction renders a good account of itself, leading to a further and more extended use of such equipment with a resultant improvement in service and economy.

In general, it is probably safe to say that rail motors should not, except in cases of emergency, be operated at more than seventy-five per cent of their rated capacity, otherwise failures will be unduly frequent and the maintenance and operating expense unduly high.

In this connection, a standard method of rating internal combustion engines or

motors for rail service should be developed as rapidly as circumstances will permit.

Experience to date has been sufficient to enable the railway companies to, in conjunction with the manufacturers cooperating through some joint body, provide against many errors of design and to formulate certain factors of limitation, especially as regards capacity rating.

It might be well to call attention to the practically universal recommendation that steam locomotives be operated normally at some seventy-five per cent of their rated capacity.

Railway service, especially passenger service, by its inexorable demands occassioned by schedule and speed requirements, exacts the utmost from its motive power, far more than is exacted in any other form of transport; especially do we realize that this is so when we take into consideration the necessity of long economic service life and the low operating cost required of rail motive power, even though, unlike marine power, it is somewhat handicapped by the necessity of its being operated by one set or class of employees and maintained by another.

On most steam railroads, the importance of labor contracts such as will facilitate the retainment in service, once qualified, of runners and maintainers of rail motor equipment is exceedingly great.

On some lines this has been accomplished in both the running and maintenance trades by establishing double seniority lists, that is the employee in addition to his original seniority as developed in steam service will, upon his being qualified on rail motor equipment, be placed on a rail motor seniority list with same date as his original date on steam seniority list. In this manner, both the employee and the equipment are protected since should there be insufficient work on rail motor equipment at any time to furnish a qualified rail motor runner or maintainer employment, he can exercise his rights in steam running or maintenance work, etc.

The Chicago, Rock Island & Pacific Railway Company, in an effort to protect both its employees, and its service and equipment, recently completed a Catechetical Instruction Book for gasoline and distillate-burning rail motor equipment. This book is the result of some twenty years' experience in the operation of gas-electric motor cars and some eight years experience with distillate-electric motor cars.

Typical repair and shopping classification for gasoline and distillate-electric rail motor cars.

Class 6 repair to be made to motor car at 100 000 miles, to condition car for additional 100 000 miles of service.

1. Trucks run from under car, wheels and motors removed; the truck frame center casting, bolsters, wearing plates, spring hangers and equalizers checked for alignment, cracks, checks, wear, etc., and any necessary repairs or replacements made. Wheels as well as bearings checked, housing, pedestal jaws, etc., and any necessary work done to restore to 100 % condition. Also all parts of the brake rigging to be restored to 100 % condition.

Gears and pinions cleaned, whitewashed and checked for cracks and wear. The gear housing, axle cap bearings, and motor support bearings to be checked and any necessary work done to restore to 100 % condition. If necessary, remove traction motor heads and check armature bearings. Clean motors thoroughly and see that brush holders and all parts are in good condition.

2. *Underframe.* Check center castings and pins, and side bearings for fit or broken parts, lubrication, etc., draft gear carrier irons, etc. Check and restore to 100 % condition all other parts of the frame including the anchors and sup-

ports for all parts suspended under the car. Battery box and fuel tanks to be checked for any necessary repairs to restore to 100 % condition. The air brakes, hand brakes, and all other parts in the underframe to be checked and repaired if necessary, and if any periodic inspection, cleaning and tests are nearly due, such work should be done.

3. *Car body.* In addition to a general cleaning and inspection of car body, special attention must be given to piping, heating system, toilets, windows, doors, hardware etc., including ventilators. All safety appliances must be checked and all such work performed as may be necessary to restore to 100 % condition. Car body to be cleaned inside and outside.

4. *Engines.* Engine base should be checked for cracks, fastenings, anchorage, etc., — lower crankcase cleaned and inspected, main and connecting rod bearings removed for inspection and any necessary work done to restore to 100 % condition. All connecting rod bolts and nuts to be renewed and all main bearing cap screws to be renewed. Cylinder heads to be removed and checked for defects, new piston rings applied, pistons and wrist pins checked, and any replacements made that may be necessary for another 100 000 miles of service. Cylinder liners to be checked for wear and if necessary new liners applied. All liners to be given a coat of corrosion-resisting paint on water jacket side. Valves, guides, seats and springs to be put in 100 % condition. Camshaft and rocker arm assemblies and roller plugs to be inspected and conditioned if necessary to make an additional 100 000 miles. Exhausts should be checked and any necessary work done to condition for an additional 100 000 miles. Remove timing gear case, inspect gears, countershaft and bearings, and condition for 100 000 miles of service.

5. Check water box for cleanliness, scale, etc., and also for cracks, and coat inside with corrosion resisting paint. Check the upper crank case and place in 100 % condition.

6. All parts of carburetor to be checked for wear and any other defects. Such corrections made as may be found necessary.

7. All parts of the ignition system including the transformers, mounting, wiring, switches, distributors, gears, bearings, etc., to be checked, and any necessary repairs made.

8. All parts of the governor, throttle and the controls, to be inspected for wear and defects, and any necessary repairs made.

9. The entire cooling system including the water pump, to be checked for defects and worn parts. All scale and obstructions removed from radiators and piping etc. The water pump to be dismantled for inspection, and all parts placed in 100 % condition.

10. All parts of lubricating system checked for wear and defects, and all parts placed in 100 % condition.

11. All piping and wiring to be checked and any necessary repairs made.

12. *Air compressors.* Make orifice test of air compressor. Check valves for leaks, and discharge pipe for carbon accummulation, and any necessary repairs made.

13. Clean out the main generator, see that all parts are in good condition and see that the generator is correctly aligned with the engine crankshaft.

14. All auxiliary motors to be given thorough inspection and test for wear and defects, and necessary repairs made.

15. All fuel tanks, water tanks, piping, etc., to be checked and all necessary repairs made.

16. All radiator shutters, warning horns, bell ringers and other miscellaneous parts to be inspected, and necessary repairs made, and tested.

17. The entire steam heating system including electrical apparatus inspected, any necessary repairs made, and tested.

18. All parts of the hot water heating system should be inspected, necessary repairs made, and tested.

19. All instruments and gages to be tested and necessary repairs made, and tested.

20. Paint trucks and touch up such other painting as may be necessary.

Class 5 repairs to be made to motor car at 200 000 miles.

1. All items included in Class 6 repairs are included in Class 5, and in addition traction motor armatures are to be cleaned, tested, and necessary repairs made, rebanded, dipped, baked, and again tested.

2. Generator bearings to be inspected and any necessary repairs made.

3. Field coils to be cleaned, painted, any necessary repairs made, and tested.

4. Leads, brush holders and supports to be placed in 100 % condition.

5. Connecting rods to be cleaned, whitewashed and checked for fractures. To be checked with standard jig for bend, twist and alignment.

Class 4 repairs to be made to motor car at 300 000 miles.

1. All items included in Class 6 repairs are included in Class 4, and in addition, due to 300 000 miles service, crankshaft and connecting rod bearing is to be compensated and adjusted to allow for crankshaft wear. Generator to be aligned accordingly.

Class 3 general repairs to be made to motor car at 400 000 miles.

1. General repairs to be made to entire equipment including car body, truck, draft gear, brake equipment, power plants, controls, auxiliaries, etc. All motor armatures to be rebanded. All armatures, field coils, etc., to be cleaned, reinsulated, baked and tested. All wiring to be tested and renewed as may be necessary. Engine crank shafts reground or renewed.

2. Connecting rods to be cleaned, whitewashed and checked for fractures, and checked on standard jig for twists, bends, and alignment.

3. Commutators to be renewed, if necessary, to continue in service until next Class 5 repair.

4. Car to be painted inside and outside, and all stencilling, numbering and marking of parts to be renewed. By following as closely as possible this repair classification, the availability should be improved and the cost of maintenance be reduced.

PART II.

General tabulation of rail motor cars in service or under construction.

a) *United States, Canada, Mexico.*

The list hereafter, giving the rail motor cars in service in these three countries, shows that the gasoline engine predominates, and moreover that, as regards the kind of transmission, the electric drive was given preference so far. Indeed, the total number of rail motor cars in service in these countries is made up as follows :

Total number of rail motor cars :	
Burning gasoline	744
— distillate	63
— oil (diesel engine) . . .	38
With mechanical drive	130
— electric drive	649
— hydraulic drive	1

It should be noted that 33 of the Chicago, Rock Island and Pacific cars shown as gasoline-electric burn distillate fuel, like practically all the Union Pacific system cars (30 in number), which are also shown as gasoline-electric.

More detailed particulars are given in the tables hereafter, in connection with these cars, whether in service or under construction. In these tables, horse power of multiple power plant cars is shown with numeral in front to indicate number of power plants, i.e. for two 300-horse power plants, total horse power is shown 2 × 300.

RAIL CARS PUT IN SERVICE BETWEEN THE YEARS 1923 AND 1932.

(United States, Canada, Mexico.)

RAILROAD.	Number of cars.	Date in service.	Type of power plant.	Total horse power.	Overall length of car.	Seating capacity.	Weight *Lb.*
Atchison, Topeka & Santa Fe	3	1925	Gas.-mech.	175	56′	56	56 340
	2	1928	Gas.-elec.	275	72′	77	105 000
	1	1928	Gas.-elec.	275	73′	76	108 500
	7	1929	Gas.-elec.	400	75′	57	133 200
	3	1929	Gas.-elec.	400	75′	57	134 500
	2	1929	Gas.-elec.	400	80′	35	133 500
	7	1929	Gas.-elec.	400	80′	35	135 700
	1	1929	Gas.-elec.	400	80′	35	136 800
	1	1930	Gas.-elec.	400	75′	57	134 800
	1	1930	Gas.-elec.	400	80′	35	135 000
	4	1931	Gas.-elec.	400	80′	28	140 700
	8	1931	Gas.-elec.	400	75′	...	133 950
	2	1931	Gas.-elec.	535	80′	...	135 830
	1	1932	Gas.-elec.	535	80′	...	139 320
	1 (*)	1932	Gas.-elec.	900	90′ 2 3/8″	...	210 500
Baltimore & Ohio	1	1923	Gas.-mech.	65	29′ 7″	22	18 150
	1	1925	Gas.-mech.	190	55′	67	56 480
	1	1925	Gas.-mech.	190	55′	25	54 000
	1	1927	Gas.-elec.	250	60′	71	93 200
	4	1927	Gas.-elec.	250	60′	71	94 000
	3	1927	Gas.-elec.	250	60′	71	94 700
	6	1928	Gas.-elec.	250	60′	71	94 700
	1	1928	Gas.-elec.	250	60′	71	99 000
	1	1928	Gas.-elec.	250	60′	16	100 900
	1	1928	Gas.-elec.	250	69′ 2″	68	154 700
	1	1929	Gas.-elec.	2 × 300	...	46	...
Boston & Maine	1	1924	Gas.-mech.	68	44′	30	29 000
	4	1925	Gas.-mech.	190	57′ 5″	45	63 660
	1	1925	Gas.-elec.	170	51′ 10″	30	67 300
	3	1925	Gas.-elec.	200	57′ 9″	44	77 500
	2	1926	Gas.-mech.	190	57′ 5″	30	63 660
	1	1926	Gas.-elec.	250	62′ 6″	42	100 100
	1	1926	Gas.-elec.	250	62′ 6″	50	94 780
	1	1926	Gas.-elec.	250	75′ 5″	86	112 000
	8	1926	Gas.-elec.	275	63′ 3″	54	96 000
	2	1926	Gas.-elec.	275	75′ 3″	84	104 000
Burlington-Rock Island	3	1929	Gas.-elec.	400	76′ 10 7/8″	...	138 000
Canadian National	1	1923	Gas.-mech.	185	56′ 9 1/2″	41	66 400
	1	1923	Stor. batt.	100	50′	50	64 180
	1	1923	Stor. batt.	100	59′ 8″	64	79 000
	4	1924	Stor. batt.	100	53′ 9″	50	69 900
	4	1925	Gas.-mech.	125	43′ 5″	43	29 000
	1	1925	Gas.-elec.	160	59′ 7″	32	45 000
	7	1925	Oil-elec.	200	63′ 1″	57	102 000
	2 (*)	1925	Oil-elec.	400	105′ 1″	121	188 000
	2	1926	Gas.-elec.	120	56′ 2″	50	70 000

(*) Articulated cars.

RAILROAD.	Number of cars.	Date in service.	Type of power plant.	Total horse power.	Overall length of car.	Seating capacity.	Weight *Lb.*
Canadian National (continued)	5	1927	Oil-elec.	300	76′ 2 1/4″	37	141 000
	1	1928	Gas.-elec.	125	56′ 2″	50	68 000
	2	1929	Gas.-mech.	40 - 90	57′ 11″	42	29 000
	1	1929	Oil-elec.	200	63′ 9 1/4″	49	110 000
	7	1930	Oil-elec.	350	76′ 2 1/4″	37	141 000
	2	1931	Oil-elec.	350	76′ 2 1/4″	37	141 000
	2	1931	Oil-elec.	300	76′ 2 1/4″	37	141 000
	2	1931	Oil-elec.	300	76′ 2 1/4″	. .	141 000
Canadian Pacific	2 (*)	1925	Gas.-mech.	100 - 150	38′	43	34 000
	2	1930	Gas.-elec.	400	72′	50	136 600
	2	1931	Gas.-elec.	400	72′	50	142 000
	2	1932	Gas.-elec.	400	72′	25	144 200
Central of Georgia	1	1928	Gas.-mech.	110	43′ 11 1/8″	29	32 000
Central Vermont	2	1926	Gas.-elec.	250	60′	59	92 360
	1	1927	Gas.-elec.	250	60′	59	92 360
	1	1927	Gas.-elec.	150	53′ 2″	22	63 800
	1	1927	Gas.-elec.	250	60′	42	100 400
Chesapeake & Ohio	1	1924	Gas.-mech.	90	43′ 5 5/16″	...	31 200
	1	1924	Gas.-mech.	90	43′ 5 5/16″	39	30 800
	1	1924	Gas.-mech.	90	43′ 5 5/16″	39	31 700
	1	1929	Gas.-mech.	90	43′ 5 5/16″	43	32 300
	1	1929	Gas.-elec.	275 - 300	79′ 7 5/8″	40	130 100
	2	1929	Gas.-elec.	275 - 300	79′ 7 5/8″	40	130 000
	1	1929	Gas.-elec.	275 - 300	79′ 7 5/8″	40	129 500
	1	1929	Gas.-elec.	275 - 300	79′ 7 5/8″	40	130 500
	1	1929	Gas.-elec.	275 - 300	79′ 7 5/8″	40	130 700
Chicago & Alton	1	1925	Gas.-elec.	185	57′ 4″	44	72 000
	1	1925	Gas.-elec.	185	55′	...	72 000
	1	1925	Gas.-elec.	185	55′	19	72 000
	1	1928	Gas.-elec.	275	72′	12	102 560
	1	1928	Gas.-elec.	275	72′	...	102 560
	1	1928	Gas.-elec.	275	72′	24	104 820
	1	1928	Gas.-elec.	275	72′	...	104 820
Chicago & Northwestern	1	1925	Gas.-elec.	175	57′ 4″	39	78 300
	3	1926	Gas.-elec.	220	70′ 6″	42	97 200
	1	1927	Gas.-elec.	220	72′	42	99 140
	1	1927	Gas.-elec.	220	72′	40	103 420
	1	1927	Gas.-elec.	220	72′	40	107 980
	1	1927	Gas.-elec.	220	72′	40	100 360
	1	1927	Gas.-elec.	220	72′	40	101 640
	1	1928	Gas.-elec.	220	72′	40	101 700
	1	1928	Gas.-elec.	220	72′	40	104 300
	1	1928	Gas.-elec.	220	72′	40	103 700
	1	1928	Gas.-elec.	275	72′	40	105 300
	5	1928	Gas.-elec.	2 × 275	65′	...	131 840
	2	1928	Gas.-elec.	275	72′	...	108 800
	1	1928	Gas.-elec.	275	72′	40	110 900

(*) Articulated cars.

RAILROAD.	Number of cars.	Date in service.	Type of power plant.	Total horse power.	Overall length of car.	Seating capacity.	Weight *Lb.*
	1	1928	Gas.-elec.	275	72′	35	106 800
	1	1928	Gas.-elec.	275	65′	53	107 200
	1	1929	Gas.-elec.	400	65′	70	122 950
	1	1929	Gas.-elec.	400	65′	70	122 950
Chicago & Northwestern (continued).	2	1929	Gas.-elec.	300	75′	40	117 050
	1	1929	Gas.-elec.	2 × 300	75′	32	151 800
	2	1929	Gas.-elec.	300	65′	...	111 700
	1	1929	Gas.-elec.	2 × 300	75′	...	154 800
	2	1929	Gas.-elec.	2 × 300	75′	...	154 800
	1	1924	Gas.-mech.	135	43′	41	41 000
	1	1925	Gas.-mech.	135	43′	40	41 000
	1	1926	Gas.-mech.	180	43′ 2″	37	43 000
	1	1926	Gas.-mech.	180	43′ 2″	22	43 000
	1	1926	Gas.-elec.	225	65′ 7″	39	98 940
	1	1927	Gas.-elec.	250	60′	42	93 920
	1	1927	Gas.-elec.	275	65′	17	108 240
	1	1927	Gas.-elec.	275	65′	12	108 340
	4	1927	Gas.-elec.	275	65′	...	107 260
	2	1927	Gas.-elec.	275	75′	57	112 280
	1	1927	Gas.-elec.	275	75′	49	113 400
	2	1927	Gas.-elec.	275	75′	37	116 300
	1	1927	Gas.-elec.	275	75′	32	115 500
	3	1927	Gas.-elec.	275	75′	24	116 000
	1	1927	Gas.-elec.	275	75′	55	112 280
	1	1928	Gas.-elec.	275	65′	77	104 200
	2	1928	Gas.-elec.	275	65′	39	106 500
Chicago, Burlington & Quincy (*)	1	1928	Gas.-elec.	275	65′	32	106 400
	1	1928	Gas.-elec.	275	65′	29	106 800
	1	1928	Gas.-elec.	275	65′	22	104 500
	5	1928	Gas.-elec.	275	65′	53	109 700
	1	1928	Gas.-elec.	275	65′	22	110 200
	5	1928	Gas.-elec.	275	65′	...	108 400
	1	1928	Gas.-elec.	2 × 120	75′	55	113 500
	1	1928	Gas.-elec.	400	75′	39	134 800
	1	1928	Gas.-elec.	275	75′	29	112 700
	2	1928	Gas.-elec.	400	75′	60	138 800
	2	1928	Gas.-elec.	275	75′	37	115 500
	1	1928	Gas.-elec.	275	75′	32	114 900
	5	1928	Gas.-elec.	275	75′	24	115 300
	1	1928	Gas.-elec.	275	75′	27	114 500
	1	1929	Gas.-elec.	400	65′	...	133 000
	1	1929	Gas.-elec.	400	65′	...	133 700
	2	1929	Gas.-elec.	400	75′	...	140 100
	4	1930	Gas.-elec.	400	75′	. .	141 600
	1	1923	Gas.-mech.	200	52′ 9″	30	45 000
	1(**)	1924	Gas.-elec.	175	60′ 3″	44	76 300
Chicago Great Western	1	1925	Gas.-mech.	200	52′ 9″	30	50 000
	1	1925	Gas.-mech.	200	52′ 9″	30	52 000
	2	1928	Gas.-elec.	275	70′ 1 3/4″	60	96 100
	1	1928	Gas.-elec.	275	64′	...	119 300

(*) Description of 1 gas.-mech. car not in use omitted.
(**) Obsolete.

RAILROAD.	Number of cars.	Date in service.	Type of power plant.	Total horse power.	Overall length of car.	Seating capacity.	Weight *Lb.*
Chicago, Milwaukee, St. Paul & Pacific	4	1927	Gas.-elec.	275	72′	...	128 700
	6	1927	Gas.-elec.	275	72′	...	128 700
	4	1927	Gas.-elec.	275	72′	44	119 000
	1	1927	Gas.-elec.	275	72′	44	119 000
	1	1929	Steam.-mech.	550	61′ 4″	...	128 000
	1	1931	Steam.-mech.	450	60′ 4″	...	139 260
Chicago, Rock Island & Pacific	1	1924	Gas.-mech.	60	37′ 10″	35	29 000
	3	1925	Gas.-elec.	200	66′ 8 7/8″	65	80 000
	1	1926	Gas.-elec.	200	51′ 7 1/8″	53	75 000
	5	1927	Gas.-elec. (*)	275	75′ 3 1/2″	77	108 400
	2	1927	Gas.-elec. (*)	2 × 275	40′ 8 3/4″	...	170 000
	8	1928	Gas.-elec. (*)	275	74′ 9 1/2″	42	112 600
	3	1929	Gas.-elec.	240	74′ 9 1/2″	42	112 400
	3	1929	Gas.-elec. (*)	2 × 400	42′ 8 3/4″	...	187 400
	7	1929	Gas.-elec. (*)	2 × 400	50′ 10 1/4″	...	189 200
	1	1929	Gas.-elec. (*)	400	74′	37	139 000
	1	1929	Gas.-elec. (*)	400	74′	...	139 000
	1	1929	Gas.-elec.	400	74′ 6 3/4″	...	137 000
	2	1930	Gas.-elec.	240	74′ 9 1/2″	39	112 400
Chicago, St. Paul, Minn. & Omaha	1	1928	Gas.-elec.	275	67′ 6 7/8″	57	100 300
	1	1928	Gas.-elec.	275	74′ 6 7/8″	80	103 200
	1	1929	Gas.-elec.	2 × 300	66′ 10 7/8″	25	147 200
	1	1929	Gas.-elec.	2 × 300	73′ 10 1/8″	20	153 900
	1	1929	Gas.-elec.	2 × 300	73′ 10 1/8″	...	152 300
	1 (**)	1929	Gas.-elec.	2 × 300	66′ 10 1/8″	30	145 600
Cleveland, Cincinnati, Chicago & St. Louis	4	1925	Gas.-mech.	225	49′ 2 1/2″	...	53 900
	4	1925	Gas.-elec.	275	57′ 4″	...	93 700
	1	1926	Gas.-elec.	250	60′	...	92 000
	2	1931	Gas.-elec.	535	75′	...	135 050
Colorado & Southern	1	1928	Gas.-elec.	400	75′	27	139 500
	1	1929	Gas.-elec.	400	75′	...	136 500
Columbus & Greenville	1	1925	Gas.-mech.	190	55′ 10″	50	53 000
	2	1928	Gas.-elec.	300	73′	17	116 400
Detroit & Mackinac	1	1929	Gas.-elec.	300	75′ 5″	38	117 240
	1	1929	Gas.-elec.	300	75′ 5″	38	116 780
Detroit, Toledo & Ironton	2 (**)	1926	Gas.-elec.	2 × 168	65′ 1 5/8″	44	124 000
Duluth, Missabe & Northern	1	1924	Gas.-mech.	2 × 104	58′ 9 1/4″	50	76 800
	1	1926	Gas.-mech.	2 × 104	67′ 6″	36	90 800
	1	1926	Gas.-mech.	2 × 104	66′	30	92 000
Erie	2	1923	Gas.-mech.	65	44′ 1 3/8″	38	30 650
	1	1924	Gas.-mech.	65	44′ 1 3/4″	38	31 240
	1	1924	Gas.-mech.	65	44′ 1 3/4″	38	31 800
	1	1924	Gas.-mech.	65	44′ 1 3/4″	38	31 080
	2	1924	Gas.-mech.	65	44′ 1 3/4″	34	31 620

(*) Distillate-electric.
(**) Obsolete.

RAILROAD.	Number of cars.	Date in service.	Type of power plant.	Total horse power.	Overall length of car.	Seating capacity.	Weight *Lb.*
Erie (continued)	1	1924	Gas.-mech.	65	44′ 1 3/4″	34	31 920
	1	1925	Gas.-mech.	175	56′ 1 1/8″	42	55 800
	1	1925	Gas.-mech.	175	56′ 1 1/8″	42	55 800
	2	1926	Gas.-mech.	175	56′ 1 1/8″	42	58 880
	1	1926	Gas.-elec.	250	61′ 1 1/8″	57	91 020
	1	1926	Gas.-elec.	250	61′ 1 1/8″	32	90 000
	1	1926	Gas.-elec.	250	61′ 1 1/8″	42	90 190
	1	1930	Oil-elec.	2 × 300	77′ 3″	...	206 808
	1	1930	Gas.-elec.	2 × 300	75′ 6″	...	177 916
	2	1930	Gas.-elec.	2 × 300	75′ 6″	53	177 600
	1	1930	Gas.-elec.	2 × 300	75′ 6″	...	176 707
	11	1931	Gas.-elec.	2 × 300	72′ 11 1/2″	54	175 752
Great Northern	1	1925	Gas.-elec.	175	59′ 7″	52	70 000
	3	1925	Gas.-elec.	175	59′ 7″	52	70 000
	1	1925	Gas.-elec.	175	59′ 7″	52	72 000
	1	1925	Gas.-elec.	250	62′ 2″	61	95 380
	3	1926	Gas.-elec.	175	59′ 9 3/4″	...	81 000
	1	1926	Gas.-elec.	175	59′ 9 3/4″	...	82 340
	2	1926	Gas.-elec.	275	59′ 9 3/4″	...	101 900
	3	1926	Gas.-elec.	275	74′ 3 1/4″	...	97 960
	2	1926	Gas.-elec.	220	59′ 7″	52	70 000
	1	1927	Gas.-elec.	250	62′	...	93 000
	1	1927	Gas.-elec.	275	74′ 3″	27	101 300
	1	1927	Gas.-elec.	275	74′ 3 1/4″	27	101 300
	1	1927	Gas.-elec.	275	73′	36	120 300
	5	1928	Gas.-elec.	275	73′	...	118 700
	1	1929	Gas.-elec.	300	73′	...	120 000
	4	1929	Gas.-elec.	400	72′	...	137 860
	1	1929	Gas.-elec.	400	72′	...	139 280
	1	1929	Gas.-elec.	3 × 135	72′	...	139 900
	1	1930	Gas.-elec.	400	72′	...	144 500
	1	1930	Gas.-elec.	415	75′	...	141 390
	1	1930	Oil-elec.	400	72′	...	147 780
Gulf, Mobile & Northern *New Orleans Great Northern*	2	1930	Gas.-elec.	535	75′	40	140 020
Huntingdon & Broad Top Mountain R. R. & Coal Co	1	1929	Gas.-elec.	2 × 300	73′	58	150 000
Illinois Central	1	1927	Gas.-mech.	190	55′	68	60 000
	3	1927	Gas.-mech.	190	55′	43	60 000
Lehigh & Hudson River	1 (*)	1928	Gas.-elec.	2 × 250	75′	52	152 380
Lehigh & New England	1	1926	Gas.-elec.	225	60′	86	86 352
	1	1928	Gas.-elec.	250	60′	81	94 980
Lehigh Valley	1	1923	Gas.-mech.	68	42′ 7 1/4″	40	29 500
	1	1925	Gas.-elec.	220	57′ 4″	...	79 760
	2	1925	Gas.-elec.	220	57′ 4″	52	76 860
	1	1925	Gas.-elec.	220	57′ 4″	22	76 860

(*) Obsolete.

RAILROAD.	Number of cars.	Date in service.	Type of power plant.	Total horse power.	Overall length of car.	Seating capacity.	Weight *Lb.*
Lehigh Valley (cont'd)	1	1925	Gas.-elec.	220	57′ 4″	42	77 560
	1	1926	Gas.-elec.	2 × 250	70′ 11″	...	132 020
	1	1926	Gas.-elec.	2 × 250	70′ 11″	...	132 020
	1	1926	Gas.-elec.	2 × 250	70′ 11″	19	128 220
	1	1926	Gas.-elec.	2 × 250	70′ 11″	19	132 680
	1	1927	Gas.-elec.	2 × 220	70′ 6″	36	126 120
	1	1927	Gas.-elec.	2 × 220	70′ 6″	16	131 900
	1	1927	Gas.-elec.	2 × 220	70′ 6″	61	126 540
	1	1927	Gas.-elec.	2 × 220	70′ 6″	51	125 550
	1	1927	Gas.-mech.	250	60′	50	90 540
	1	1927	Gas.-elec.	2 × 275	70′ 11″	19	138 500
	1	1927	Gas.-elec.	200	57′ 4″	52	81 520
	1	1927	Gas.-elec.	2 × 275	70′ 11″	24	137 560
	1	1928	Gas.-elec.	2 × 220	71′ 4 11/16″	21	133 000
	1	1928	Gas.-elec.	2 × 220	71′ 4 3/4″	21	134 360
	1	1928	Gas.-elec.	2 × 275	72′ 7 1/2″	26	144 470
	1	1928	Gas.-elec.	220	58′ 7 1/2″	49	79 580
	1	1929	Gas.-elec.	220	58′ 7 1/2″	66	81 280
	1	1929	Gas.-elec.	2 × 300	72′ 9 1/4″	51	154 200
	1	1929	Gas.-elec.	2 × 300	72′ 8 1/4″	21	152 300
	1	1930	Gas.-elec.	2 × 300	72′ 9 1/4″	42	153 500
	1	1930	Gas.-elec.	2 × 300	72′ 8 1/4″	18	152 300
Long Island	1	1927	Gas.-mech.	68	43′ 5 5/16″	43	29 900
Louisiana & Arkansas	1	1928	Gas.-mech.	68	42′ 7 5/16″	43	29 000
	1	1928	Gas.-mech.	175	55′	56	53 000
Louisiana & Northwest	1	1931	Gas.-mech.	200	58′	36	57 000
Louisville & Nashville	1	1928	Gas.-elec.	275	60′	58	94 400
Maryland & Pennsylvania	1	1927	Gas.-elec.	275	62′	67	91 900
	1	1929	Gas.-elec.	2 × 220	62′	57	122 720
Midland Valley	2	1928	Gas.-elec.	175	70′ 7 3/8″	24	110 000
	1	1929	Gas.-elec.	175	70′ 7 3/8″	24	110 000
Minneapolis & St. Louis	3	1930	Gas.-elec.	300	75′	32	127 800
	4	1930	Gas.-elec.	400	75′	...	146 250
	1	1931	Gas.-elec.	300	75′	32	130 000
	1	1931	Gas.-elec.	400	75′	...	146 000
	2	1931	Gas.-elec.	400	75′	...	145 000
Minneapolis, St. Paul & Sault Ste Marie	1	1925	Gas.-elec.	175	60′ 2″	52	79 900
Missouri-Kansas-Texas	1	1925	Gas.-mech.	180	55′	34	54 960
	1	1925	Gas.-mech.	175	57′ 4″	37	77 600
	1 (*)	1932	Gas.-elec.	400	75′	...	158 000
	1 (*)	1932	Gas.-elec.	415	75′	...	151 000
Missouri Pacific	1	1924	Gas.-mech.	85	43′ 5 5/16″	30	29 000
	1	1924	Gas.-mech.	85	43′ 5 5/16″	26	29 000

(*) In process of delivery.

RAILROAD.	Number of cars.	Date in service.	Type of power plant.	Total horse power.	Overall length of car.	Seating capacity.	Weight *Lb.*
Missouri Pacific (cont'd)	1	1924	Gas.-mech.	85	43′ 5 5/16″	36	29 000
	1	1925	Gas.-elec.	85	43′ 5 5/16″	24	29 000
	1	1926	Gas.-elec.	85	43′ 5 5/16″	28	29 000
	2	1926	Gas.-elec.	85	43′ 5 5/16″	30	29 000
	1	1926	Gas.-elec.	225	57′ 4″	48	83 980
	1	1926	Gas.-elec.	225	57′ 4″	42	82 620
	2	1926	Gas.-elec.	225	72′ 9 5/16″	40	97 000
	1	1926	Gas.-elec.	225	72′ 9 5/16″	40	100 500
	1	1927	Gas.-elec.	225	71′ 3 7/8″	86	106 000
	3	1927	Gas.-elec.	225	51′ 9 5/8″	48	80 400
	2	1927	Gas.-elec.	225	51′ 9 5/8″	46	80 400
	2	1931	Gas.-elec.	400	77′ 0 3/4″	...	164 500
Mobile & Ohio	2	1926	Gas.-elec.	220	72′ 9 5/16″	40	93 800
	1	1927	Gas.-elec.	220	74′ 3 5/16″	40	93 800
	2	1927	Gas.-elec.	2 × 220	74′ 3 5/16″	27	128 800
	3	1928	Gas.-elec.	2 × 220	74′ 3 5/16″	...	128 920
National Railways of Mexico	1	1925	Gas.-elec.	105	59′ 10″	57	45 500
	1	1926	Gas.-mech.	76	32′	25	22 300
	1	1926	Gas.-mech.	76	32′	37	19 200
	1	1926	Gas.-mech.	76	32′	35	19 200
	1	1928	Gas.-mech.	25	17′ 2″	15	6 400
	2	1928	Gas.-mech.	35	30′ 8″	35	17 600
New York Central	1	1925	Gas.-mech.	190	58′ 1 3/8″	...	65 900
	1	1925	Gas.-mech.	190	58′ 0 7/8″	50	56 300
	1	1925	Gas.-mech.	190	58′ 0 7/8″	52	57 000
	1	1925	Gas.-mech.	190	58′ 0 7/8″	52	61 200
	1	1925	Gas.-mech.	190	58′ 0 7/8″	52	58 000
	1	1925	Gas.-mech.	190	58′ 0 7/8″	47	60 400
	1	1925	Gas.-mech.	190	58′ 0 7/8″	47	57 000
	1	1926	Gas.-mech.	190	58′ 0 7/8″	52	61 500
	1	1927	Oil-elec.	200	75′ 10 1/2″	48	186 700
	1	1928	Gas.-elec.	250	74′ 10 3/4″	74	119 500
	1	1928	Gas.-elec.	275	74′ 10 3/4″	74	123 100
	1	1928	Gas.-elec.	300	75′	58	128 600
	1	1928	Gas.-elec.	300	75′	58	128 000
	1	1928	Gas.-elec.	2 × 120	76′ 5 1/2″	75	116 200
	1	1928	Gas.-elec.	250	74′ 10 3/4″	40	123 900
	1	1928	Gas.-elec.	250	74′ 10 3/4″	40	123 600
	1	1928	Gas.-elec.	250	74′ 10 3/4″	40	124 100
	1	1928	Gas.-elec.	250	74′ 10 1/4″	40	123 800
	1	1928	Gas.-elec.	250	74′ 10 3/4″	40	126 400
	1	1928	Gas.-elec.	250	74′ 10 3/4″	40	123 700
	1	1928	Gas.-elec.	2 × 220	75′ 6″	39	147 600
	1	1928	Gas.-elec.	2 × 220	75′ 6″	39	147 900
	1	1928	Gas.-elec.	2 × 220	75′ 6″	39	147 800
	1	1929	Gas.-elec.	2 × 250	75′ 6 3/4″	69	160 900
	1	1929	Gas.-elec.	2 × 275	75′ 6 3/4″	31	159 990
	1	1929	Gas.-elec.	350	75′	58	129 975
New York, New Haven & Hartford	1	1923	Gas.-hydr.	180	60′ 8″	60	52 800
	1	1924	Gas.-mech.	120	41′ 10″	35	41 520

RAILROAD.	Number of cars.	Date in service.	Type of power plant.	Total horse power.	Overall length of car.	Seating capacity.	Weight *Lb.*
New-York, New Haven & Hartford (cont'd)	1	1924	Gas.-mech.	120	41′ 10″	30	41 520
	8	1924-1925	Gas.-mech.	120	41′ 10″	45	41 520
	1	1925	Gas.-mech.	180	51′ 4 1/2″	35	49 600
	1	1925	Gas.-mech.	120	51′ 4 1/2″	37	49 600
	8	1925	Gas.-mech.	120	51′ 4 1/2″	50	49 600
	1	1925	Gas.-elec.	200	62′ 2″	65	82 540
	5	1926	Gas.-elec.	250	75′ 10″	72	107 250
	6	1927	Gas.-elec.	250	75′ 10″	72	107 250
	1 (*)	1930	Gas.-elec.	250	75′ 10″	88	106 120
	1 (*)	1932	Gas.-elec.	250	62′ 9″	52	85 000
New York, Ontario & Western	1	1925	Gas.-mech.	120	42′ 6″	38	39 000
	1	1926	Gas.-elec.	250	75′ 9″	69	110 000
Northern Pacific	1	1924	Gas.-elec.	175	57′ 4″	57	78 400
	1	1925	Gas.-elec.	175	57′ 4″	37	77 920
	2	1925	Gas.-elec.	175	57′ 4″	42	77 920
	3	1925	Gas.-elec.	175	57′ 4″	52	78 600
	1	1926	Gas.-elec.	220	72′ 9 5/16″	52	90 920
	1	1926	Gas.-elec.	220	72′ 9 5/16″	22	92 040
	1	1926	Gas.-elec.	220	72′ 9 5/16″	32	92 040
	1	1927	Gas.-elec.	275	74′ 3 5/16″	32	104 260
	2	1927	Gas.-elec.	275	74′ 3 5/16″	...	101 670
	1	1929	Gas.-elec.	275	77′ 0 1/2″	52	114 800
	2	1929	Gas.-elec.	300	77′ 2 1/2″	32	126 200
	3	1929	Gas.-elec.	300	77′	34	128 640
	1	1929	Gas.-elec.	300	77′	20	127 960
	1	1929	Gas.-elec.	300	77′	44	126 220
	2	1930	Gas.-elec.	2 × 300	77′	...	166 350
Oklahoma City-Ada-Atoka	1	1927	Gas.-mech.	225	50′	30	50 000
	1	1929	Gas.-mech.	225	50′	...	50 000
Pennsylvania	1	1923	Gas.-mech.	68	42′ 5/16″	39	29 900
	1	1923	Gas.-mech.	68	42′ 5/16″	43	29 900
	1	1923	Gas.-mech.	68	42′ 5/16″	36	30 500
	1	1924	Gas.-mech.	68	42′ 5/16″	36	30 510
	1	1924	Gas.-mech.	68	42′ 5/16″	45	29 900
	1	1924	Gas.-mech.	68	42′ 5/16″	43	29 900
	1	1924	Gas.-mech.	100	42′ 5/16″	42	32 060
	1	1925	Gas.-mech.	115	43′ 7″	29	40 100
	1	1925	Gas.-mech.	115	43′ 7″	41	40 100
	1	1925	Gas.-mech.	175	55′	65	54 140
	1	1925	Gas.-mech.	175	55′	63	54 210
	1	1925	Gas.-elec.	250	60′	62	90 000
	2	1926	Gas.-elec.	250	60′	62	90 840
	1	1926	Gas.-mech.	175	55′	53	58 100
	1	1926	Gas.-mech.	175	55′	43	58 100
	2	1926	Gas.-elec.	250	60′	60	90 000
	1	1928	Gas.-elec.	2 × 175	73′	73	132 500
	3	1928	Gas.-elec.	2 × 175	73′	73	132 000
	2	1928	Gas.-elec.	2 × 175	73′	73	131 700
	1	1928	Gas.-elec.	2 × 120	73′	71	115 160

(*) Purchased second-hand from another railroad.

RAILROAD.	Number of cars.	Date in service.	Type of power plant.	Total horse power.	Overall length of car.	Seating capacity.	Weight *Lb.*
	1	1928	Gas.-elec.	275	73′	65	121 600
	4	1928	Gas.-elec.	275	73′	73	122 775
	1	1928	Gas.-elec.	275	73′	70	122 300
	10	1929	Gas.-elec.	2 × 175	73′	77	129 200
Pennsylvania (cont'd)	1	1929	Gas.-elec.	2 × 175	73′	74	128 628
	2	1929	Gas.-elec.	2 × 175	73′	73	128 500
	2	1929	Oil-elec.	330	73′	72	133 475
	1	1929	Gas.-elec.	400	73′	72	141 225
	5	1930	Gas.-elec.	415	75′	66	139 400
Pittsburgh, Lisbon & Western	1	1924	Gas.-mech.	68	43′ 6″	24	30 300
Pittsburg, Shawmut & Northern	1	1925	Gas.-mech.	175	55′	54	54 000
	1	1926	Gas.-mech.	175	55′	54	54 000
	2	1923	Gas.-mech.	68	42′ 7 1/2″	26	31 320
	1	1925	Gas.-elec.	250	62′ 5 1/4″	50	90 250
	3	1927	Gas.-elec.	250	62′ 2 1/2″	32	98 260
	1	1928	Gas.-elec.	2 × 165	73′	39	137 100
	1	1929	Gas.-elec.	3 × 120	73′	39	133 500
	1	1929	Oil-elec.	300	73′	34	137 300
Reading	1	1929	Oil-elec.	300	73′	19	138 400
	1	1929	Gas.-elec.	2 × 300	73′	24	162 700
	1	1929	Gas.-elec.	3 × 120	73′	64	135 400
	1	1929	Gas.-elec.	3 × 120	73′	64	135 790
	2	1929	Gas.-elec.	2 × 250	73′	24	164 120
	1	1929	Gas.-elec.	2 × 250	73′	39	156 720
	1	1930	Gas.-elec.	2 × 300	73′	24	163 800
Richmond, Fredericksburg & Potomac	1	1928	Gas.-elec.	2 × 300	73′	41	146 000
	1	1929	Gas.-elec.	2 × 300	73′	41	146 000
	2	1926	Gas.-elec.	2 × 200	73′ 3 5/8″	34	109 500
	4	1927	Gas.-elec.	275	75′ 0 1/2″	...	110 500
	1	1927	Gas.-elec.	275	75′ 0 1/2″	...	118 300
Seaboard Air Line	1	1927	Gas.-elec.	275	75′ 0 1/2″	...	117 000
	1	1927	Gas.-elec.	275	75′ 0 1/2″	...	107 800
	2	1927	Gas.-elec.	275	75′ 0 1/2″	...	106 480
	2	1927	Gas.-elec.	275	74′ 3 5/16″	...	104 500
	1	1929	Gas.-elec.	3 × 135	74′	74	132 120
Southern Pacific	1	1929	Gas.-elec.	2 × 300	73′	55	154 600
	4	1930	Gas.-elec.	400	74′	34	158 400
	5	1930	Gas.-elec.	2 × 300	73′	54	167 500
	2	1929	Gas.-elec.	300	70′	...	118 000
Southern Pacific—Texas and Louisiana Lines	1	1929	Gas.-elec.	300	70′	...	122 200
	1	1929	Gas.-elec.	300	71′ 4″	...	119 100
	2	1930	Gas.-elec.	300	74′	...	126 400
	6	1930	Gas.-elec.	400	74′	...	140 500

RAILROAD.	Number of cars.	Date in service.	Type of power plant.	Total horse power.	Overall length of car.	Seating capacity.	Weigh Lb.
St. Louis—San Francisco	2	1925	Gas.-elec.	200	67′ 4″	60	76 80
	4	1926	Gas.-elec.	250	61′	51	86 24
	2	1928	Gas.-elec.	220	62′ 3″	62	89 44
	5	1929	Gas.-elec.	400	72′	...	131 34
St. Louis Southwestern	2	1929	Gas.-mech.	80	43′ 10 5/8″	35	33 00
	1	1929	Gas.-mech.	15-30	38′ 6 1/2″	23	29 00
Temiskaming & Northern Ontario	1	1927	Gas.-elec.	250	73′	77	90 00
Tonopah & Tidewater	1	1928	Gas.-elec.	275	72′	45	108 00
Toronto, Hamilton & Buffalo	1	1927	Gas.-elec.	275	61′ 11 5/16″	47	94 60
Union Pacific System	1	1925	Gas.-elec.	180	58′ 2″	50	73 98
	1	1925	Gas.-mech.	200	73′ 10″	38	79 50
	1	1926	Gas.-elec.	225	73′ 1″	50	86 80
	2	1927	Gas.-elec.	300	64′ 8″	52	92 30
	4	1927	Gas.-elec.	225	75′	70	97 70
	1	1927	Gas.-elec.	275	75′	70	102 92
	4	1927	Gas.-elec.	275	75′	24	99 70
	1	1927	Gas.-elec.	275	75′	36	95 98
	1	1928	Gas.-elec.	300	73′ 3″	...	102 52
	4	1928	Gas.-elec.	275	73′ 5″	74	111 40
	2	1928	Gas.-elec.	300	75′ 6″	44	112 28
	1	1928	Gas.-elec.	275	75′	20	105 30
	1	1929	Gas.-elec.	300	73′ 3″	...	101 80
	3	1929	Gas.-mech.	200	73′ 10″	38	79 50
	2	1930	Gas.-elec.	300	75′ 6″	70	114 60
Wabash	1	1926	Gas.-elec.	126 (*)	57′ 4″	...	76 56
	1	1926	Gas.-elec.	126 (*)	57′ 4″	27	77 92
Wheeling & Lake Erie	1	1927	Gas.-elec.	250	60′	54	88 54
	1	1927	Gas.-elec.	250	60′	21	92 47
	1	1927	Gas.-elec.	250	60′	21	92 29
Wichita Valley	1	1930	Gas.-elec.	400	76′ 10 7/8″	...	141 60

(*) S. A. E. rating.

RAILCARS ON TRIAL OR UNDER CONSTRUCTION.
(United States, Canada, Mexico.)

PURCHASER.	Number.	Motor or trailer.	Type of power plant.	Horse power.	Seating capacity.	Weight *Lb.*	Builders.
Aberdeen & Rockfish . . .	1	Motor.	Gas.-mech.	125	38	40 100	Sterling-Brill.
Bellevue & Cascade . . .	1	Motor.	Gasoline.	33.75	...	6 400	Hercules-Twin Coach.
Bessemer & Lake Erie . .	1	Motor.	Gasoline.	22.50	12	5 000	Hercules-Twin Coach.
Chicago, Burlington & Quincy	1	Artic. train.	Oil-elec.	600	72	180 000	Winton-General Electric-Budd.
Chicago, Mil., St. Paul & Pacific	5	Motor.	Gasoline.	46.8	8	14 000	Coach & Car-Buda.
Escanaba & Lake Superior.	1	Motor.	Gasoline.	25	14	9 000	Fairbanks-Morse.
Great Northern	1	Motor.	Oil-elec.	400	22	158 000	Standard Steel-Westinghouse.
Midland Terminal	1	Motor.	Gasoline.	200	8	26 000	Company Shops, Pierce-Arrow.
Pullman Company	4	Trailer.	...	...	...	...	Pullman.
Union Pacific	1	Motor train.	Diesel-elec.	600	116	180 000	Pullman.
		Motor train.	Oil-elec.	900	124	...	Pullman.
Chicago Great Western . .	4	Motor.	Gas.-elec.	600	...	178 000	Elec.-M-West-Pullman.
	1	Motor.	Gas.-elec.	400	22	156 300	Stand. S-West-Sterl.
Georgia Northern	1	Motor.	Gasoline.	75	25	20 000	Edwards Ry. M. Car.
Pennsylvania	1	Motor.	Oil-elec.	125	30	25 000	Cummings-G.E.-Budd.
	1	Motor.	Oil-elec.	125	46	25 000	Cummings-G.E.-Budd.
Reading	1	Motor.	Oil-elec.	125	47	22 000	Cummings-West-Budd.
Rio Grande Southern . . .	1 (*)	Motor.	Gasoline.	40	6	5 300	Company shops.
	1	Motor.	Gasoline.	50	7	10 300	Company shops.
	1	Motor.	Gasoline.	50	9	14 800	Company shops.
	1	Motor.	Gasoline.	50	9	15 200	Company shops.
Texas & Pacific	1	Motor.	Gas.-elec.	400	...	45 000	A. La France-West.-Budd.
	1	Trailer.	...	...	65	30 000	Budd.
Canadian Pacific	2	Motor.	Gas.-elec.	400	...	150 000	Elec.-M.-West Ottawa Car.
	2	Motor.	Gas.-elec.	400	25	144 200	Ottawa Car.

(*) 3-foot gage.

b) *Other countries.*

The general tabulation hereafter shows, according to the replies received, the rail cars in service or under construction on January 10, 1933, in respect of railroads belonging to countries other than those of Continental Europe, and with the exception of the U.S.A., Canada and Mexico.

These Railroads are the following :
Ceylon Government Railway.
Chosen Government Railways.

Egyptian State Railways.
Great Southern Railways (Ireland).
Great Northern Railway (Ireland).
London Midland and Scottish Railway.
Great Western Railway.
London and North Eastern Railway.
South Indian Railway.
South African Railways and Harbours.

RAILCARS PUT IN SERVICE BETWEEN THE YEARS 1923 TO 1933.

RAILROAD.	Number of cars.	Date in service.	Type of power plant.	Total horse power.	Notes.	Seating capacity.	Weig tons
Ceylon Government Ry.	10	1927	Steam engine. Sentinel-Cammell.	80	...	70	22.
	3	Do.	Do.	80	...	44	18.2(N
	4	1928	Do.	80	...	134	33.
	7	Do.	Do.	100	...	70	29
	3	Do.	Do.	100	...	44	25
	3	Do.	Steam engine-Clayton.	100	...	72	29
Chosen Government Rys.	2	1929	Steam engine, Sentinel.	100	...	74	36.
	7	1928	Gas.-mech. Ford.	33	Narrow gage.	21	4.
	2	1929	Gas.-mech. Buda.	41	Do.	28	6.
	4	1933	Diesel-mech.	220	...	56	22.
	27	1930	Gas.-mech. Waukesha.	107	...	100	25.
	6	Do.	Do.	62	Narrow gage.	45	12.
	2	1933	Diesel-mech. Benz.	110	...	100	25.
Egyptian State Rys.	5	1928	Steam engine-Clayton.	150	Articulated.	114	46.
	1	1927	Do. Do.	100	Single.	65	27.
	5	1930	Do. Birmingham.	150	Articulated.	115	49.
	6	Do.	Do. Do.	150	Do.	111	49.
	2	Do.	Do. Do.	150	Single.	47	34
Great Southern Rys. (Ireland)	4	1928	Do. Sentinel-Cammell.	100	...	55	20.
	2	1928	Gas.-mech. Drewry.	70	...	30	8
	2	1927	Do. Do.	40	...	28	5.
	2	1929	Steam engine-Clayton.	85	...	66	28
	4	Do.	Do. Do.	85	...	67	28
	2	1932	Drumm-electric. Battery driven.	140	Sets of 2 coaches.	140	70
Great Northern Ry. (Ireland)	1	1932	Diesel-mech.	100	...	32	18.
	1	Do.	Do.	110	...	32	21
London Midland Scottish Ry.	13	1927	Steam engine. Sentinel-Cammell.	100	...	44	22.
	1	1930	Do.	100	...	44	27
Great Western Ry.	23	...	Steam engine.	...	...	...	45

RAILROAD.	Number of cars.	Date in service.	Type of power plant.	Total horse power.	Notes.	Seating capacity.	Weight, *tons.*
	24	1927	2 cyl. steam engine-Sentinel-Cammell.	100	...	59	28 tons.
	45	1928	6 cyl. steam engine-Sentinel-Cammell.	100	...	59	31 tons.
ndon & North Eastern Ry.	1	1933	Diesel-electric.	250	Articulated.	60	42 tons.
	1	1930	2 × 6 cyl. steam engine-Sentinel-Cammell.	2×200	With trailer.	122	105 tons.
	5	Do	Do. Do.	2×250	Do.	48	41 tons.
	4	Do.	1 × 6 cyl. Do.	125	Do.	59	29 tons.
uth Indian Ry.	2	1915	Gas.-mech.	45	...	70	11.10 t.
	1	1926	Do.	65	...	80	13.10 t.
	1	1927	Gas.-mech.	100	...	45	...
	1	Do.	Do.	2 × 74	...	4 to 6 t.	11.1 t.
	1	1928	Do.	2 × 90	...	42	11.8 t.
	1	Do.	Do.	2 × 90	...	60	12 tons.
th African Rys.	2	1929	Do.	2 × 90	...	49	11.7 t.
	1	1929	Steam engine-Clayton.	100	..	70	25 tons.
	12	1931	Gas.-mech.	2 × 90	...	34 to 49	29.5 t.
	1	1929	Do.	2 × 90	...	30	21.5 t.N.G.
	1	1926	Do.	60	...	26	6.7 t.N.G.

RAILCARS ON TRIAL OR UNDER CONSTRUCTION.

PURCHASER.	Number.	Motor or trailer.	Type of power plant.	Horse power.	Seating capacity.	Weight, *tons.*	Builders.
t Northern Ry (Ireland) .	1	Motor.	Diesel-mech.	90	49/44	15 tons.	Walker Bros.-Gardner.
don Midland Scottish Ry. .	3	Do.	Diesel-hydr.	130	40	10.5 t.	Leyland .
don North Eastern Ry. .	2	Trailer.	Diesel-elec.	250	56/70	42.5 t.	Armstrong-Whitworth.
	1	Motor.	Do.	95	70	18.5 t.	Do.
t Western Ry.	1	Do.	Diesel-mech.	130	78	...	...
h Africain Rys.	1	Trailer.	Gas.-mech.	2×150	52	35 tons.	Drewry Car Co.- Parsons Marine Engineering Co.
	1	Do.	Gas.-hydr.	2×225	68	49 tons.	Henschel & Sohn.

PART III.

Particulars relating to rail motor cars belonging to the railroads which replied to the questionnaire.

a) *Predominating types of rail motor cars.*

Rail motor cars which Railroad Administrations deemed interesting in respect of their possible future development are represented diagrammatically in figures 1 to 11.

The Ceylon Government Railway points out that it is not likely that the steam type of rail car will be increasingly used in the future. Cars of this

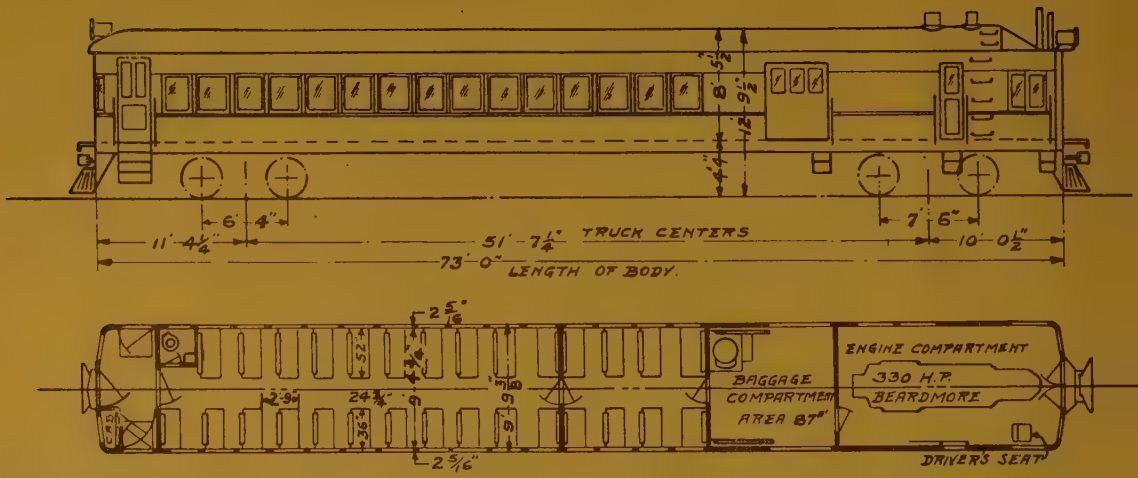


Fig. 1. — 330-H.P., class O.W.E. 330, oil-electric railcar, Pennsylvania Railroad.

Passenger compartment	One class, 72 seats.
Baggage compartment	90 sq. ft., 6 000 lb.
Mail compartment	None.
Toilet compartment	W. C.
Underframe	O. H. S.
Coupler	Conway Torley-Janey, 9".
Buffer	Pullman.
Possibility of coupling up (with other railcar and one-man drive)	No.
Possibility of hauling one or several trailers	Yes.
Body	Copper bearing steel.
Ventilation	Roof ventilators.
Heating	Peter Smith coal-fired hot water heater.
Inside lighting	32-volt, 25-watt lamps.
Track lighting by the headlights	Yes.
Kind of transmission	Electrical.
Driving bogies	One.
Engine	One, Westinghouse Beardmore diesel, 330-H.P., 6 cyl., 8 1/4" bore, 12" stroke, 800 r.p.m. max.
Starting	Storage battery.
Generator	One, Westinghouse, type 477 B, 600 volts, 420 amp.
Traction motors	Two, Westinghouse, type 569 C4; 250 H.P., 660 volts, 210 amp.
Remote control	Electro-pneumatic.
Wheels	Rolled steel.
Axle boxes	Hyatt, roller bearing.
Brakes	Westinghouse, type A.M.L. air brake with safety control features.
Storage batteries	Two lead-acid type, 16 cells, 225 amp./h. capacity.
Location of radiators	One on roof at front end of car.
Total weight, empty	130 875 lb.
— in working order	133 475 lb.
Maximum power developed by engine in service	300 H.P.
Two-direction drive	Double end control; driver's compartment at each end.
Maximum speed	60 m.p.h.

type will probably be replaced by diesel rail cars.

The Chosen Government Railways own 1 steam railcar and 42 gasoline-engined railcars with mechanical drive, 10 of which are for narrow-gage track. Whereas all these cars were put into service between 1928 and 1930, in 1933 this System introduced 2 diesel-engined railcars with mechanical transmission. They are equipped with a single 110-H.P. Benz engine and the transmission is of the Cotta type.

The Great Northern Raiway (Ireland)

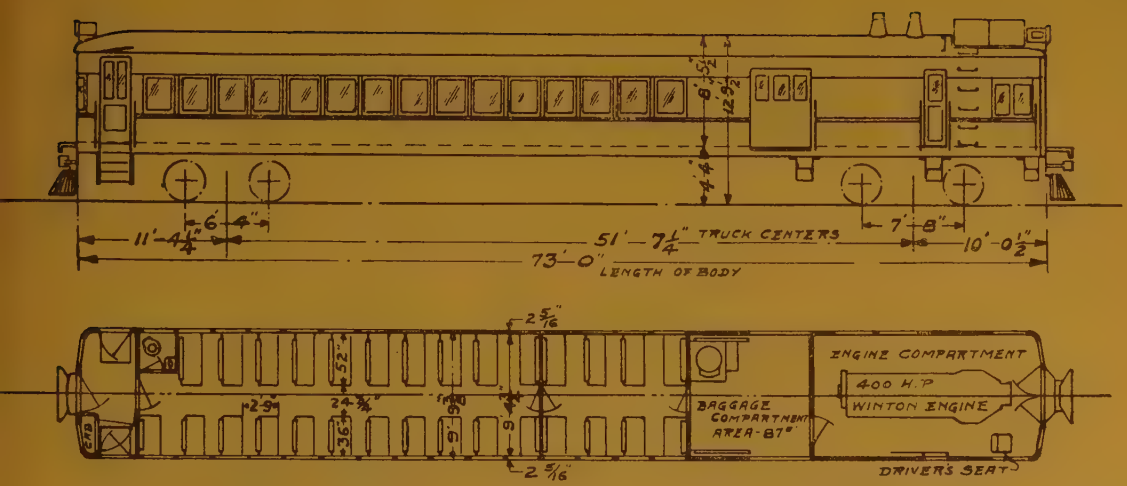


Fig. 2. — 400-H.P., class G.E.G. 400, gasoline-electric railcar, Pennsylvania Railroad.

Passenger compartment	One class, 72 seats.
Baggage compartment	90 sq. ft., 6 000 lb.
Mail compartment	None.
Toilet compartment	W. C.
Underframe	O. H. S.
Coupler	Conway Torley-Janey, 9".
Buffer	Pullman.
Possibility of coupling up (with other railcar and one-man drive)	No.
Possibility of hauling one or several trailers	Yes.
Body	Copper bearing steel.
Ventilation	Roof ventilators.
Heating	Peter Smith coal-fired hot water heater.
Inside lighting	32-volt, 25-watt lamps.
Track lighting by the headlights	Yes.
Kind of transmission	Electrical.
Driving bogies	One.
Engine	One Winton gasoline, 400 H.P., 8 cyl.; 8" bore, 10" stroke, 900 r.p.m. max.
Starting	Storage battery.
Generator	One, G.E., type DT 513 A, 600 volts, 540 amp.
Traction motors	Two G.E., type 297; 220 H.P., 600 volts, 280 amp.
Remote control	Electro-pneumatic.
Wheels	Rolled steel.
Axle boxes	Hyatt roller bearing.
Brakes	Westinghouse type A.M.L. air brake with safety control features.
Storage batteries	One, lead-acid type, 16 cells, 225 amp.-hr. capacity.
Location of radiators	Two on roof at front end of car.
Total weight, empty	138 325 lb.
— in working order	141 225 lb.
Maximum power developed by engine in service	400 H.P.
Two-direction drive	Double end control. Driver's compartment at each end.
Maximum speed	60 m.p.h.

owns two 110-H.P. diesel-driven rail cars with mechanical transmission (fig. 7 and 8); no decision has been taken as yet as regards the adoption of a given type of car.

The Great Southern Railways (Ireland) own 10 steam rail cars, 4 gasoline rail cars with mechanical drive, and two 400-H.P. accumulator-driven articulated rail cars (fig. 9, pp. 56 and 57).

The rail cars of the London Midland and Scottish Railway are all steam-driven (Sentinel). However, this Company has on trial or under construction

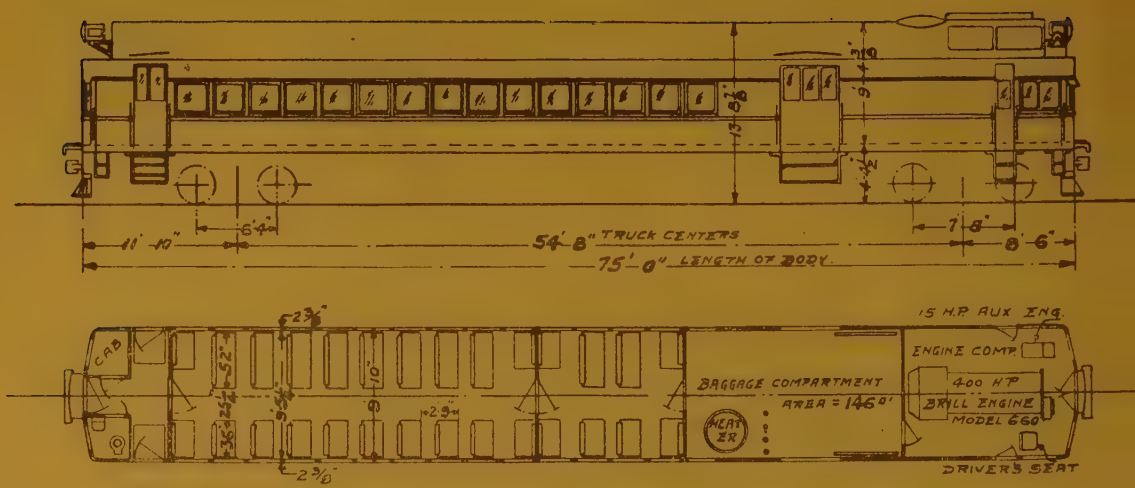


Fig. 3. — 415-H.P., class G.E.G. 415, gasoline-electric railcar, Pennsylvania.

Passenger compartment	One class, 66 seats.
Baggage compartment	146 sq. ft., 4 000 lb.
Mail compartment	None.
Toilet compartment	W. C.
Underframe	O. H. S.
Coupler	Conway Torley-Janey, 9".
Buffer	Brill.
Possibility of coupling up (with other railcar and one-man drive)	No.
Possibility of hauling one or several trailers	Yes.
Body	Copper bearing steel.
Ventilation	Utility exhaust type in roof.
Heating	Otis oil-fired steam boiler.
Inside lighting	32-volt, 25-watt lamps.
Track lighting by the headlights	Yes.
Kind of transmission	Electrical.
Driving bogies	One.
Engine	One. Brill model 660 gasoline, 415 H.P., 6 cyl.; 8 3/4" bore, 10 1/2" stroke; 950 r.p.m. max.
Main generator	One, G. E., type DT 524; 600 volts, 560 amp.
Auxiliary generator	One G. E., type 1143, Forma-I, 37 volts.
Traction motors	Two G.E., type 710 A; 220 H.P.; 600 volts, 280 amp.
Remote control	Electro-pneumatic.
Wheels	Rolled steel.
Axle boxes	Hyatt roller bearing.
Brakes	Westinghouse type A.M.L. air brake with safety control features.
Storage batteries	One, lead-acid type, 16 cells; 300 amp./h. capacity.
Starting	Storage battery.
Location of radiators	Four on roof at front end of car.
Total weight, empty	135 .600 lb.
— in working order	139 400 lb.
Maximum power developed by engine in service	400 H.P.
Two-direction drive	Double end control. Driver's compartment at each end.
Maximum speed	60 m.p.h.

3 light rail cars with Leyland diesel engine and hydraulic transmission.

The London and North Eastern Railway only uses Sentinel steam rail cars, except for one 250-H.P. diesel-electric unit. Two 250-H.P. Armstrong-Whitworth diesel-electric rail cars are furthermore under trial or being built, and one 95-H.P. diesel railbus from the same builder (see figs. 5 and 6).

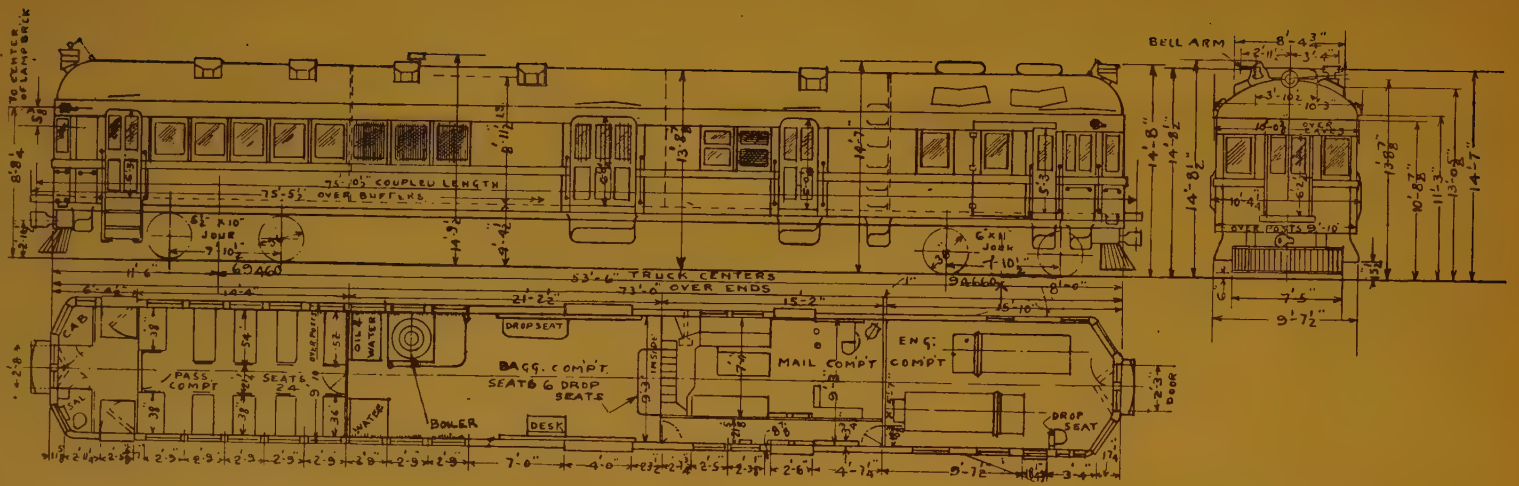


Fig. 4. — 500-H.P. gas-electric railcar No. 69, Reading Company. Passengers, baggage and mail.

Builder	J. G. Brill Co.
Date	May 1929.
Seating capacity	Pass. comp't: 24; baggage comp't: 6.
Weight	164 120 lb.
Framing	Steel.
Engines	2 Brill West. 250 H.P.
Horse power (total)	500.
Cylinders	Six, 7 1/4" × 8".
Generators	2 Westinghouse, 181-C.
Motors	4 — 559 D-2.
Gear ratio	19 : 52.
Speed, 1/2 % grade	60 m.p.h.
— 1 % grade	48 m.p.h.
— 2 % grade	37 m.p.h.
— with one 40-t. trailer, 1/2 % grade	48 m.p.h.
— with one 40-t. trailer, 1 % grade	38 m.p.h.
Speed, with one 40-t. trailer, 2 % grade	25 m.p.h.
— with two 40-t. trailers, 1/2 % grade	37 m.p.h.
— with two 40-t. trailers, 1 % grade	28 m.p.h.
— with two 40-t. trailers, 2 % grade	17 m.p.h.
Mail capacity	5 000 lb., 778 cu. ft.
Baggage capacity	9 000 lb., 1 435 cu. ft.
Heating	Otis steam boiler.
Lighting	Electric.
Upholstering	Blue plush.
Ventilators	Garland.
Fuel capacity	500 gallons.
Inside finish	Mahogany.
Tractive effort, 5 m.p.h.	19 200 lb.
— 10 m.p.h.	12 900 lb.
— 20 m.p.h.	6 100 lb.
— 50 m.p.h.	2 800 lb.

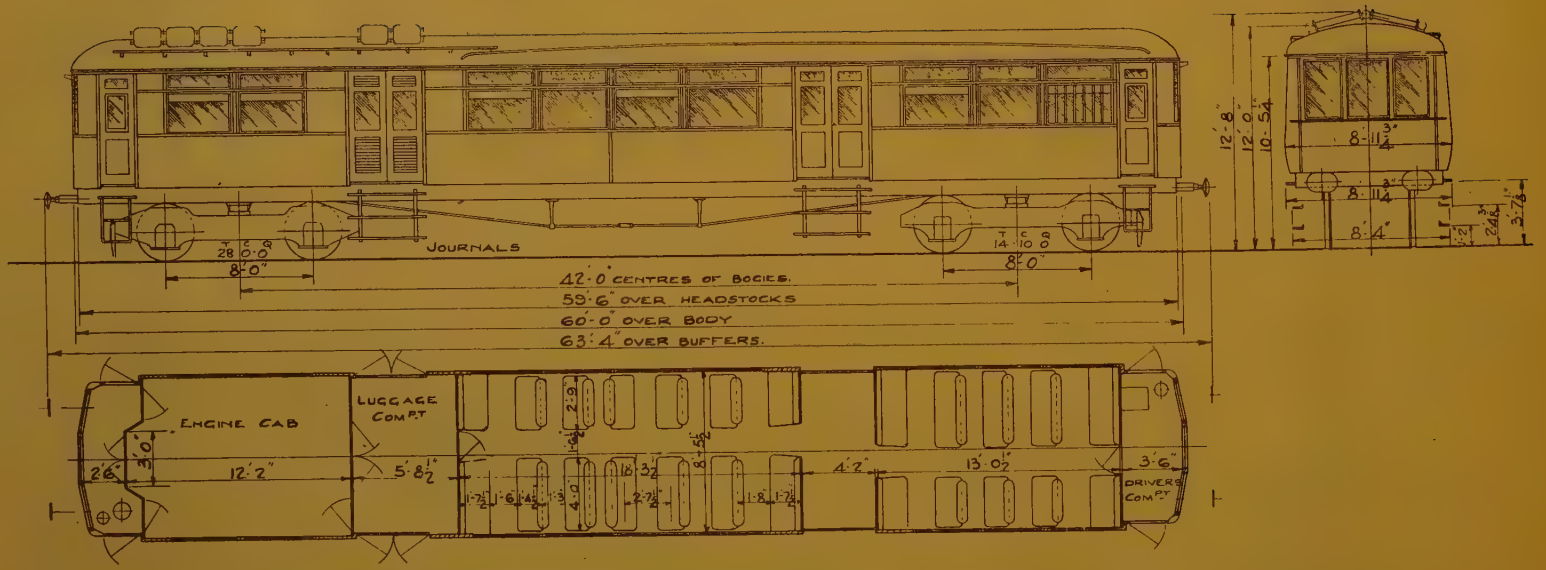


Fig. 5. — Diesel-electric railcar, built by W.C. Armstrong-Whitworth & Co., 1932.
London and North Eastern Railway.

1 open compartment : 60 seats. — 2 driver's compartments.
1 luggage compartment to carry 1 ton. — 1 engine cab.
Vacuum and hand brake. — Electric light.
Weight in working order : 42 t. 10 cwt.

Fig. 6. — Diesel-electric railbus for single-unit working, built by W.C. Armstrong Whitworth & Co. London and North Eastern Railway.

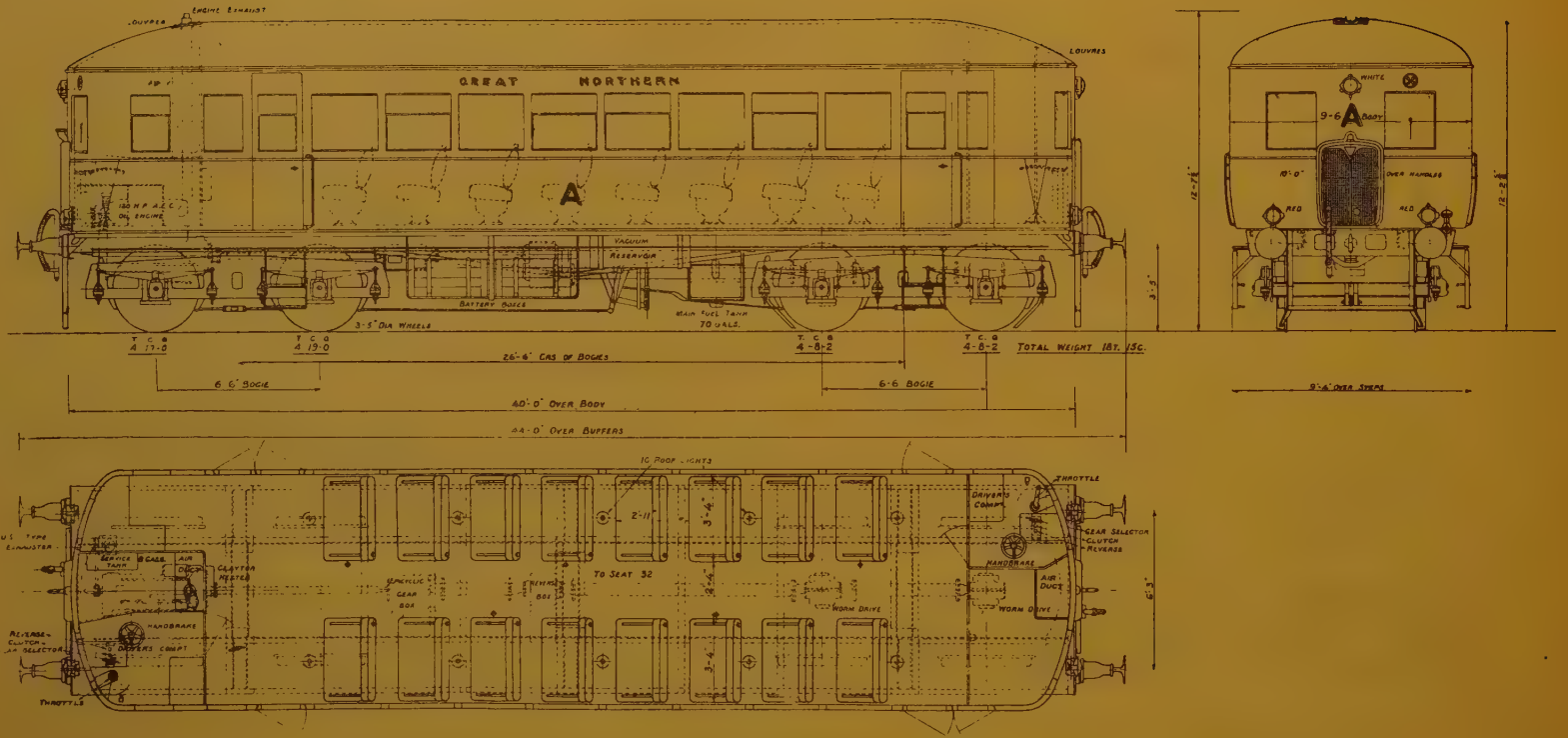


Fig. 7. — 100-B.H.P. Diesel railcar, model A, with mechanical transmission. May 1932. Great Northern Railway, Ireland.

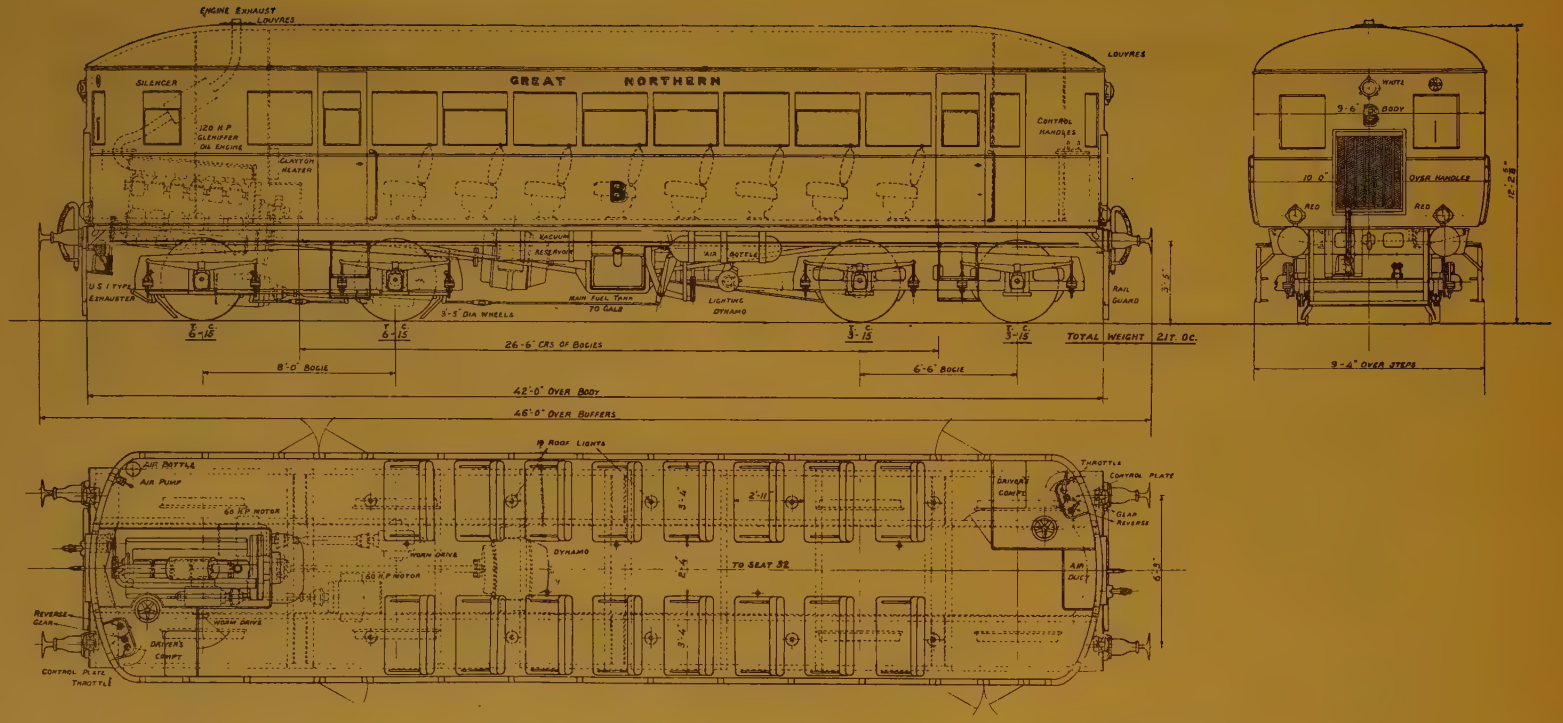


Fig. 8. — 110-B.H.P. Diesel railcar, model B, with electrical transmission, June 1932.
Great Northern Railway, Ireland.

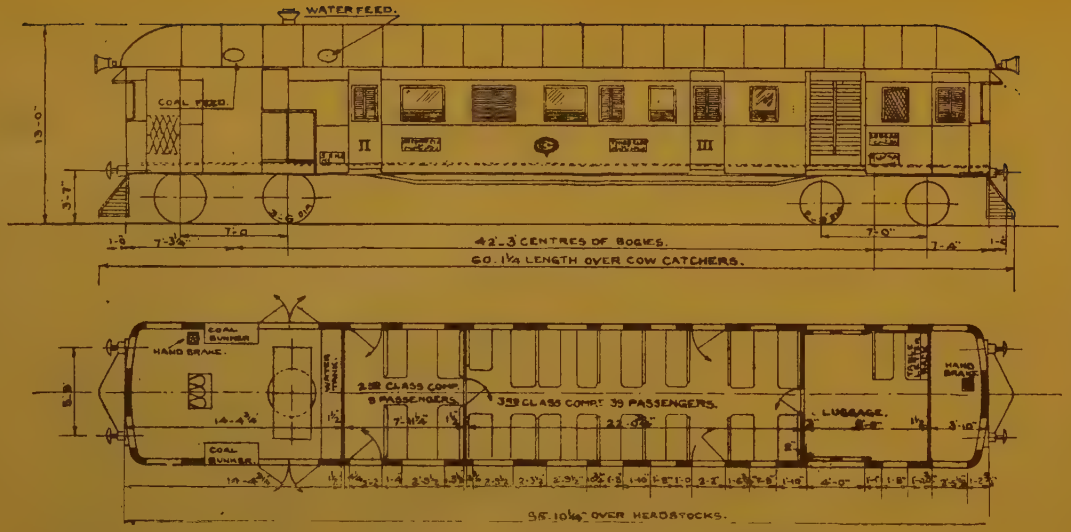


Fig. 10. — Steam railcar, Egyptian State Railways.

Seating capacity.	2d class	8
	3rd class.	39
	Total	47
Number in service		2.
Builder		Birmingham.
Date of construction		1930.
Converted at Boulac in		1931.
Capacity of water tank		2.00 tons.
— coal bunker.		1.00 ton.
Lighting		Electric.

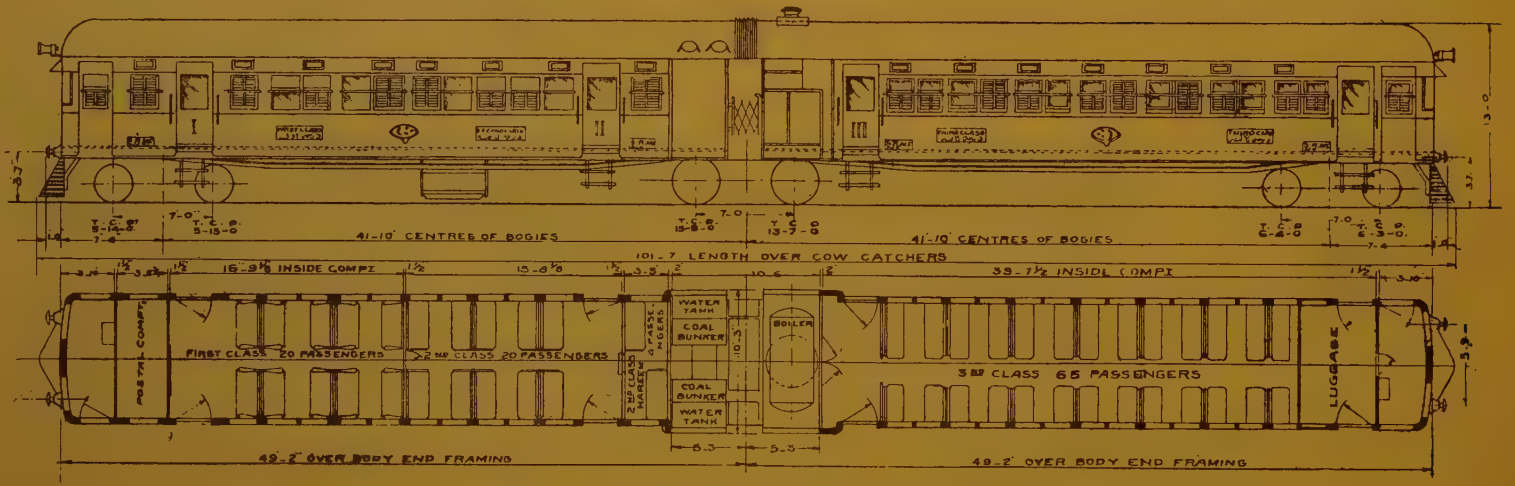


Fig. 11. — Articulated steam railcar, Egyptian State Railways.

Number in service		5.
Builder		Birmingham.
Date of construction		1930.
Seating capacity.	1st class	20
	2nd —	24
Weight in working order		52.12 tons.
Capacity of water tank		2.00 tons.
— coal bunker		1.00 ton.

With the exception of one steam rail car, the South African Railways only use gasoline rail cars with mechanical drive. They have also under trial a gasoline car with hydraulic transmission.

b) *Diagrams showing car acceleration and transmission efficiency.*

The diagrams, figures 12 to 14, show the acceleration and maximum speeds, on the various grades, of the typical Pennsylvania Railroad cars.

The acceleration curve of the London Midland and Scottish Railway diesel rail car with hydraulic transmission shown in figure 15 is of particular interest. This Railway points out that :

1. The maximum deceleration may be taken as equal to 3.5 feet per sec. per sec.

2. The efficiency of the hydraulic drive is amply in excess of 80 % in most of the cases of indirect drive, and even 90 % in the case of direct drive. The efficiency may be taken as equal to 92-94 %.

c) *Characteristics of the engines.*

The information supplied by the Administrations in connection with the constructional characteristics of the more typical internal combustion engines is summed up in the appended tables, pp. 52 to 57.

The diagrams, figures 16 to 20, show the power, torque and fuel consumption curves of the internal combustion engines used as prime movers on the more typical rail cars of the Pennsylvania Railroad, and the Great Northern Railway (Ireland).

Practically, all diesel engines are of the 4-stroke, 6-cylinder type. Great diversity is found in the methods of injection : direct mechanical injection (Pennsylvania Railroad, Reading Company, Great Northern Railway, Ireland) ; pre-combustion chamber (Reading Company) ; swirl type Ricardo combustion chamber (Great Northern Railway, Ireland) ; forechamber type(London and North Eastern Railway) ; Leyland combustion chamber (London Midland and Scottish Railway). The angular speed varies between 775 r.p.m. (London and North Eastern Railway) and 2 000 r.p.m. (Great Northern, Ireland & London Midland and Scottish Railway).

The three starting methods are in use : self-contained electric starting gear; main generator working as a motor excited by a storage battery; finally, compressed air.

d) *Particulars relating to transmissions.*

As typical information supplied by the railway companies, we give the very complete data furnished by the Pennsylvania Railroad (figs. 21 to 23).

e) *Wheels, axles and bogies.*

As a rule, the wheels used are of the normal railroad type. The Great Northern of Ireland uses lightened-out wheels.

The mileage run between two tire reconditionings varies between 30 000 and 70 000.

The Reading Company mentions the use of wheel flange lubricators.

Some companies use roller bearing axle boxes on driving axles as well as carrying axles (Pennsylvania Railroad, Great Northern of Ireland, London Midland and Scottish Railway). The South African Railways use plain bearings on driving axles and roller bearings on carrying axles. Isothermos axle boxes are used by the London and North Eastern Railway on diesel rail cars, and plain bearings on Sentinel steam cars.

The Chosen Government Railways use roller and plain bearing axle boxes.

The use of wheels running loose on their axles has not been reported.

f) *Braking.*

Several Companies mentioned the use

PRINCIPAL CHARACTERIST

—	*Pennsylvania Railroad.*			*Reading. Company*
Engines	330-H.P. diesel.	400-H.P. gasoline.	415-H.P. gasoline.	Diesel and g
A) Cycle	4	4	4	4 and 2
Ignition	Compression.	Spark.	Spark.	Compressi and spar
Type of head	« I » direct injection.	« I » carburetor.	« F » carburetor.	Precombusti chamber, air chamb direct inject
B) Number of cylinders	6	8	6	5
Bore	8 1/4″	8″	8 3/4″	7 1/4″
Stroke	12″	10″	10 1/2″	8″
Speed (r.p.m.)	800	900	950	1 100
Nominal horse power	300	385	400	...
Peak horse power	330	400	415	...
Max. power in service	300	400	400	250
C) Number of crankshaft main bearings	7	9	7	7
Type of bearings	Plain.	Plain.	Plain.	Plain
Metal used	Babbitt.	Babbitt.	Babbitt.	Bronze-babb ball or roll
Number of crankshaft connecting rod bearings	6	8	6	...
Type of bearings	Plain.	Plain.	Plain.	...
Metal used	Bronze.	Babbitt.	Babbitt.	...
D) Valve gear	...	...	...	2 intake a 2 exhaust cylinder.
E) Type of ignition	Solid Westinghouse fuel pump.	Delco battery.	Magneto.	...
F) Cooling system :				
Pump	Centrifugal.	Centrifugal.	Centrifugal.	Centrifuga
Type of radiator	Tubular, finned.	Tubular, finned.	Tubular, finned.	...
Draft	Natural.	Nat. and forced.	Forced.	Forced.
Normal temperature	170° F.	170° F.	170° F.	150-180° F
Max. allowable temperature	200° F.	200° F.	200° F.	200° F.
Special cold weather precautions	Shutters on radiators.	Car heating system may be interconnected.	Steam heating under radiator.	...
G) Lubrication and control	Force feed.	Force feed.	Force feed.	Force feed
Operation	Under pressure.	Under pressure.	Under pressure.	Under pressu
Control	Pressure, controlled by spring-loaded bypass.		By high and low-pressure relief valves.	Connected with throtti

(*) Railbus.

F ENGINES.

reat Northern Ry. (Ireland).		*London North Eastern Ry.*		*London Midland & Scottish Ry.*	*South African Rys.*
Diesel A.	Diesel B.	Diesel (*).	Diesel.	Diesel.	Gasoline.
4 ompression.	4 Compression.	4 Compression.	4 Compression.	4 Compression.	4 Spark.
cardo swirl e combustion chamber.	Direct injection.	Forechamber type.		Leyland combustion chamber.	...
6	6	6	6	6	6
4 1/2″	6″	4 5/16″	8 5/8″	4 5/8″	3 1/2″
5 19/32″	7″	6″	11″	6″	5″
2 000	900	1 700	775	2 000	2 000
...	...	95	250	130	65
130	...	...	...	130	...
110	110	...	275	130	90
7	7	7	7	7	4
Plain. ead bronze nd tin-base babbitt.	Plain. Gun metal white-metal lined.	Roller. ...	Plain. White metalled.	Plain. Steel shells lined with white metal.	Plain. White metal.
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
inary poppet.	Horizontally opposed.	Overhead poppet valves.		Overhead poppet valves.	...
...	...	...	...	...	...
entrifugal.	Centrifugal.	...	...	Centrifugal.	...
Tubular.	Tubular.	Tubular.	Tubular.	...	...
Natural.	Natural.	...	...	Natural.	Forced.
184° F.	184° F.	140 to 167° F.		185° F.	180° F.
...	...	...	...	200° F.	200° F.
ered at night.	Covered at night.	Automatic device for draining radiators.		...	...
Force feed.	Force feed.	Force feed.	Force feed.	Gear type pump.	Splash and oil pump.
der pressure.	Under pressure.	Under pressure.	Under pressure.	...	...
...	...	By speed of engine.		...	...

—	*Pennsylvania Railroad.*			*Reading Company.*
H) Starting gear :				
Drive	← Storage battery and main generator →			Storage batt and main generator.
Control	← Magnetic switches. →			Magnetic swit
I) Kinds of metal used				
in pistons	← Aluminum alloys. →			Aluminum all
in connecting rods	← Steel. →			High-carbo steel forgin
in crankshaft	← Steel. →			0.40 carbon s heat treate
in valves	← Alloy steel. →			Silchrome st
in valve gear	← Steel. →			Steel.
J) Fuel pump and injectors	Westinghouse system.	Carburetors.		2 Zenith ca
K) Throttle—Method of working	Electro-pneumatically operated through master-controller lever.	Connected with controlling point of bypass of oil.	Manually operated lever.	Electro-pneumatic
L) Weight of engine with flywheel	6 933 lb.	11 100 lb.	8 280 lb.	...
Weight without flywheel	5 887 lb.	...	...	...
Weight of fuel	1 440 lb.	1 540 lb.	2 460 lb.	...
Weight of lubricating oil	495 lb.	200 lb.	300 lb.	...
Weight of cooling water	680 lb.	1 160 lb.	797 lb.	...
Fuel used	Fuel oil.	Gasoline.		Gasoline.
General particulars of fuel		← Above 62 octane rating. →		
Flash	Min. 137° F.	...	...	...
Pour test	Max. 0° F.	...	...	...
Viscosity at 70° F.	Max. 80 seconds.	...	...	...
Distillation test below 460° F.	Min. 10%, max. 35 %.	...	...	...
Distillation test below 675° E.	Min. 90 %.	...	...	...
Fuel which can be substituted	None.	None.	None.	...
Fuel consumption in lb. per H.P./ hour full load	0.42 (*).	...	0.65 (*).	...
3/4 load	...	...	...	...
1/2 load	...	...	...	...
Consumption of lubricating oil per H.P.-hour.	...	...	...	...
M) What special precautions taken to protect the engine when carried on the bogie?	Not carried on the bogie.			...

(*) Full speed.

Great Northern Ry (Ireland).		*London North Eastern Ry.*		*London Midland & Scottish Ry.*	*South African Rys.*
Air motor starting.		Storage battery and main generator.		Electric starter.	
...	...	...	...	...	...
Aluminum alloys. Nickel-chrome steel.	Aluminum alloys. Steel drop forgings.	Aluminum alloys. Nickel chrome steel.	Aluminum alloys.	Aluminium alloys. 3.5 % nickel steel heat treated.	... ...
Nickel-chrome steel.	High-carbon steel.	Alloy steel.		Ni.-chrome steel case-hardened.	...
Silchrome steel.	Chromium steel.	Alloy steel.	Jessop's steel.	Ni.-chrome steel.	...
Steel.		Alloy steel.		Hadfield's steel.	...
Bosch pump and sprayers.		Sulzer pumps Bosch injectors.		CAV Bosch pumps.	Marvel carburetor.
Lever control.		Electric.		Arens pushpull control.	Hand controls.
1 477 lb.	3 750 lb.	Eng. and gen.,	4.3 tons.	1 700 lb.	...
...	Flyw. 346 lb.	1 1/2 tons.			
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
Shell light Dieseleum. 0.880 sp. gravity.		Shell light Dieseleum. 0.865 sp. gravity. 212° F. flashpoint.		Shell light Dieselum.	Gasoline.
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	0.425	8 miles per gallon.	4.5 miles per gallon.	0.42 pint/B.H.P.-hr.	...
...	0.42	...	...	0.40 do.	...
...	0.44	...	...	0.42 do.	...
0.5 pint per mile.	0.75 pint per mile.	...	...	0.01 pint.	...
...	...	...	...	...	...

—	*Pennsylvania Railroad.*		*Reading Company.*
Insulation of body against noise and vibration from the engine . .	None.	Fibre composition insulating material between bedplate and car framing.	Rubber and spring mounted.
N) How often is engine overhauled?		150 000 miles.	125 000 miles.
Parts systematically requiring attention	Pistons, rings, cylinder linings, valves and seats, bearings, timing gears, fuel pumps, crankshafts gaskets.	Pistons, rings, cylinder linings, valves and seats, bearings, exhaust pipes, gaskets.	...
Parts failing frequently	Connecting rod, bearings.	Valves and seats.	Vacuum system gaskets, air system, ignition switches.
Cause of failure	Excessive pressure.	Excessive heat.	...
Remedy adopted	Changed to bronze metal bearing from babbitt type.	Replaceable valve seats with Stellite face screwed in type.	...

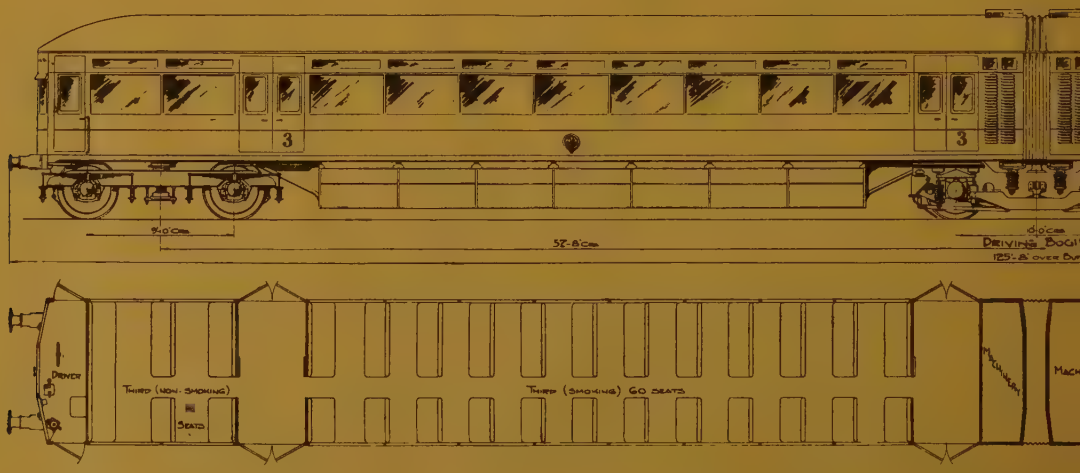
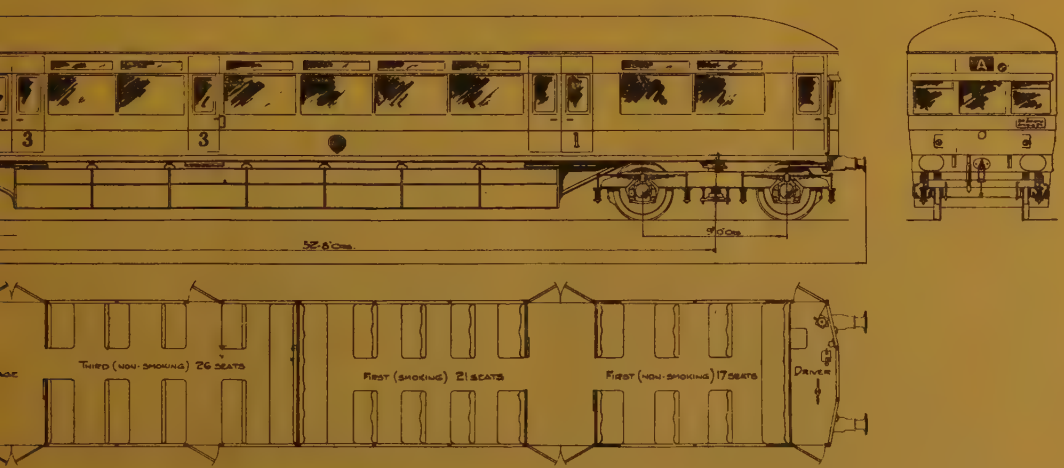


Fig. 9. — 400-H.P. battery-driven c

Passengers	2 classes, 140 seats, no standing.
Luggage	Area = 55 sq. ft.
Underframe	Steel.
Body	Wood.
Possibility of coupling with another railcar and one-man drive	Yes, with cars of the same type.
Hauling of trailers	Yes.
Ventilation	Louvres over windows.
Inside lighting	Electric.
Transmission	Geared.

Great Northern Ry. (Ireland).	*London North Eastern Ry.*	*London Midland & Scottish Ry.*	*South African Rys.*
Rubber blocks I″ thick.	Felt and rubber insulation.	Floor covering material.	Engine mounted on rubber pad, engine covers insulated on the inside.
50 000 miles.	No experience yet.	15 000 miles.	30 000 miles.
... ...	... ...	...	...
... ...	... ...	...	...
... ...	... ...	...	...
... ...	... ...	...	...



car, Great Southern Railways, Ir eland.

Wheels	Forged steel discs with steel tyres.
Axle boxes	Roller bearing.
Brakes	Vacuum, acting on all wheel rims.
Power	Normal : 400 B.H.P. Maximum : 800 B.H.P.
Two direction drive	2 driver's compartments.
Acceleration	1 m.p.h. per second.
Braking	2 m.p.h. per sec.
Total weight	70 Engl. tons.

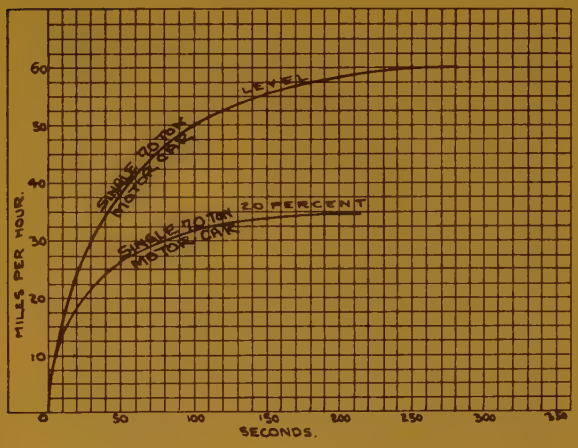
Pennsylvania Railroad.

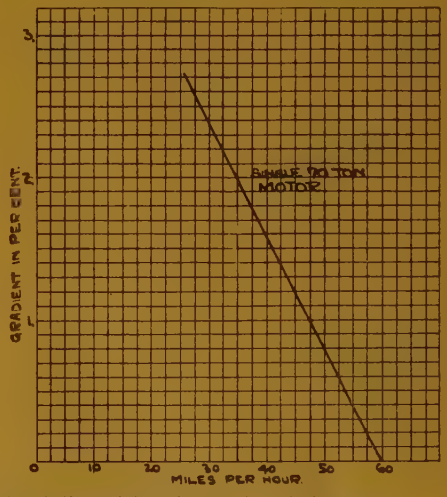
Electromotive Pullman railcar.

400-H.P. Winton model 148 gasoline engine.

Curves { Starting at the nominal H.P.
Maximum braking.
Stopping distances, brakes off, motor thrown out.

Curve showing maximum sustained speed, in terms of the gradient.





Curves shown are for a single car and are derived curves, and not those taken from actual tests. They assume that car is fully loaded and that maximum H.P. is available from tthe prime mover.
Data for maximum braking curves and stopping distance curves with brakes off not available.

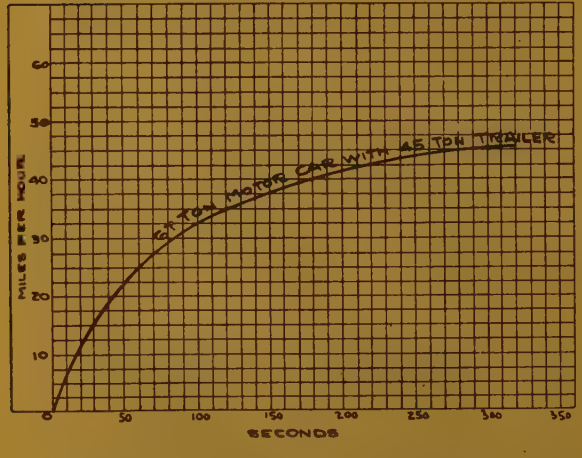
Fig. 12.

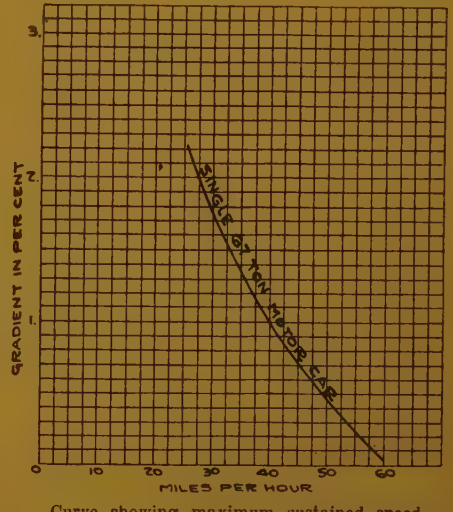
Pennsylvania Railroad.

Westinghouse Pullman railcar.

300-H.P. Westinghouse diesel engine.

Curves { Starting at the nominal H.P.
Maximum braking.
Stopping distances, brakes off, motor thrown out.





Curve showing maximum sustained speed, in terms of the gradient.

Acceleration curve was taken from data procured from test run with car hauling one 45-ton trailer. — Curve showing maximum speed in terms of the gradient is a derived curve.
Data for acceleration curves on various grades, maximum braking curves, and stopping distance curves with brakes off not available.

Fig. 13.

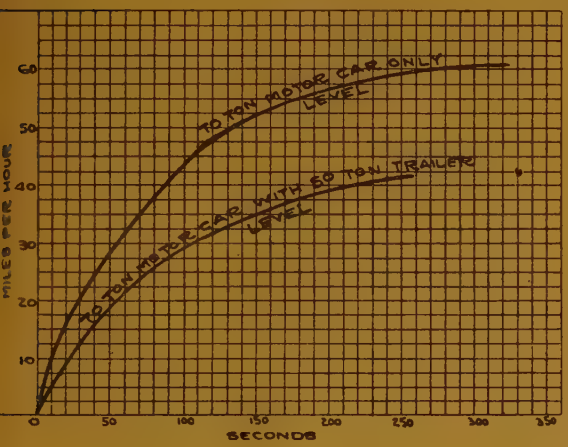
Pennsylvania Railroad.

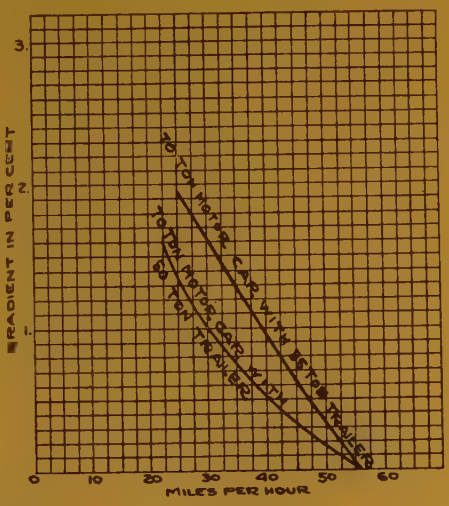
Brill railcar.

415-H.P. Brill model 660 gasoline engine.

Curves { Starting at the nominal H.P. Maximum braking. Stopping distances, brakes off, motor thrown out.

Curve showing maximum sustained speed, in terms of the gradient,





Acceleration curves plotted from data procured on test runs. — Curves showing maximum sustained speed in terms of the gradient are derived curves.

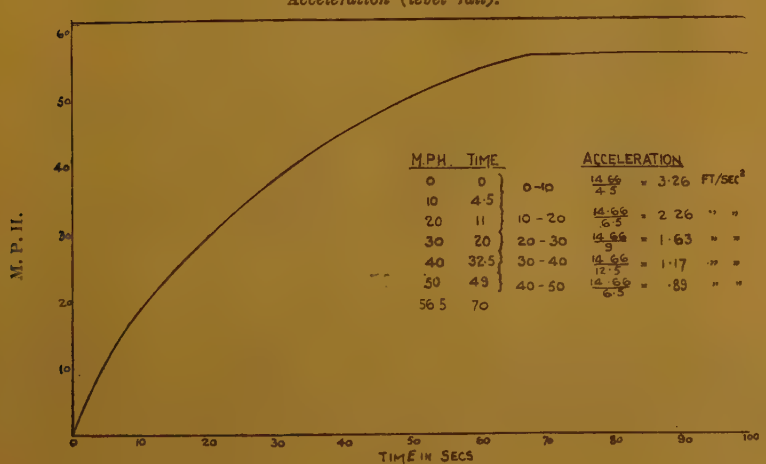
Data for acceleration curves on various grades, maximum braking power curves, and stopping distance curves with brakes off not available.

Fig. 14.

London Midland & Scottish Railway railcar.

Gross weight (full load) = 13.2 tons.

Acceleration (level rail).



M.P.H.	TIME		ACCELERATION
0	0	0-10	$\frac{14.66}{4.5}$ = 3·26 FT/SEC²
10	4·5		
20	11	10-20	$\frac{14.66}{6.5}$ = 2·26 " "
30	20	20-30	$\frac{14.66}{9}$ = 1·63 " "
40	32·5	30-40	$\frac{14.66}{12.5}$ = 1·17 " "
50	49	40-50	$\frac{14.66}{6.5}$ = ·89 " "
56·5	70		

Fig. 15.

Pennsylvania Railroad.

Brill railcar.
415-H.P. Brill, model 660, gasoline engine.

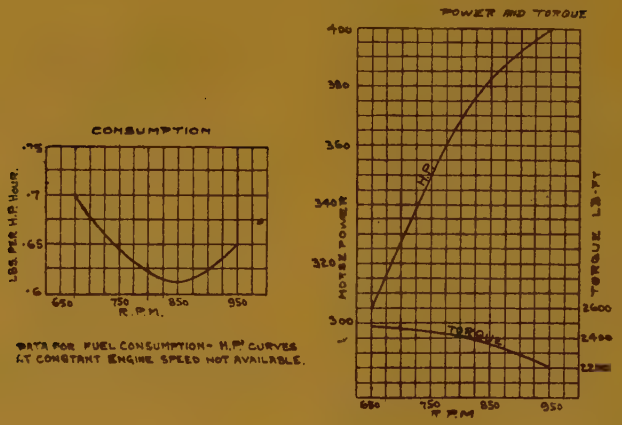


Fig. 16.

Pennsylvania Railroad.

Westinghouse Pullman railcar.
300-H.P. Westinghouse diesel engine.

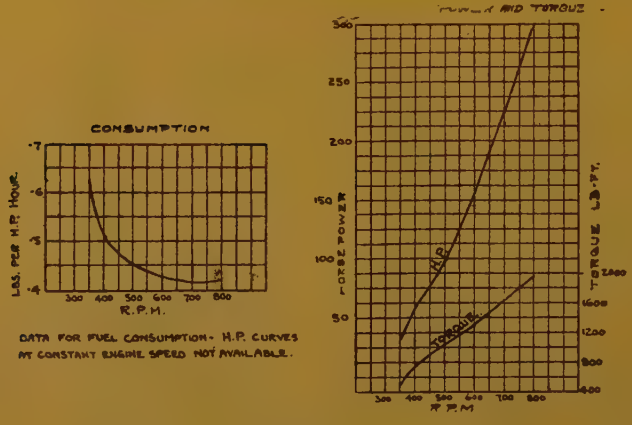
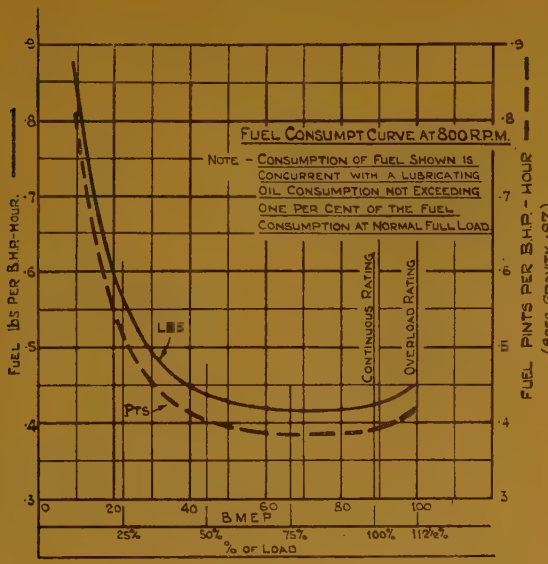


Fig. 17.

of the vacuum brake, others the compressed air brake, direct or automatic.

The London and North Eastern Railway, on its diesel railbus, and the London Midland and Scottish Railway on its Leyland rail motor cars, use drum brakes similar to the automobile type. The use of the electro-magnetic brake has not been reported.



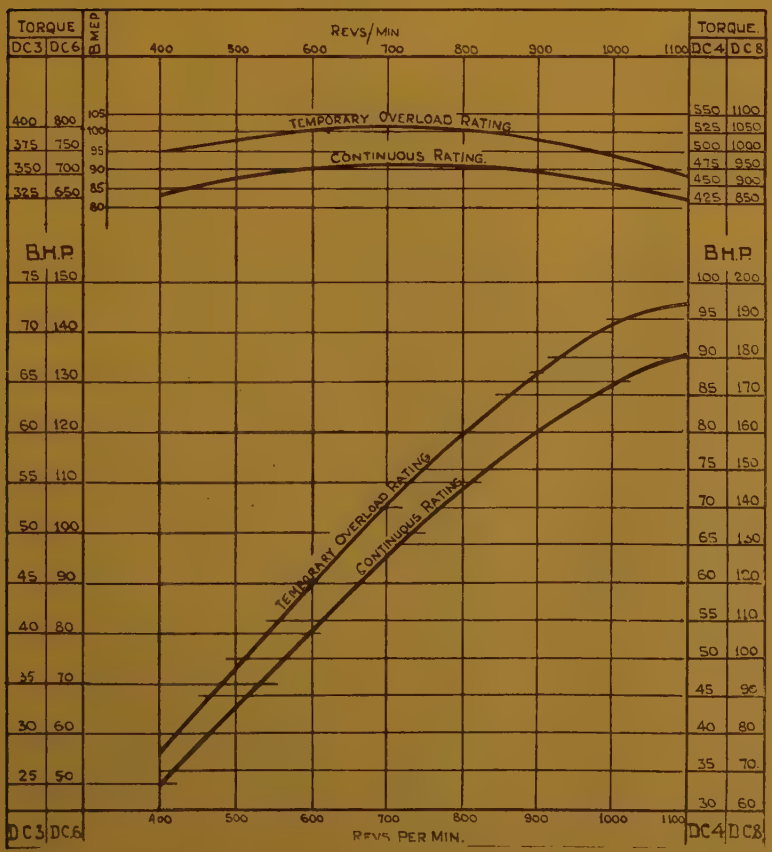
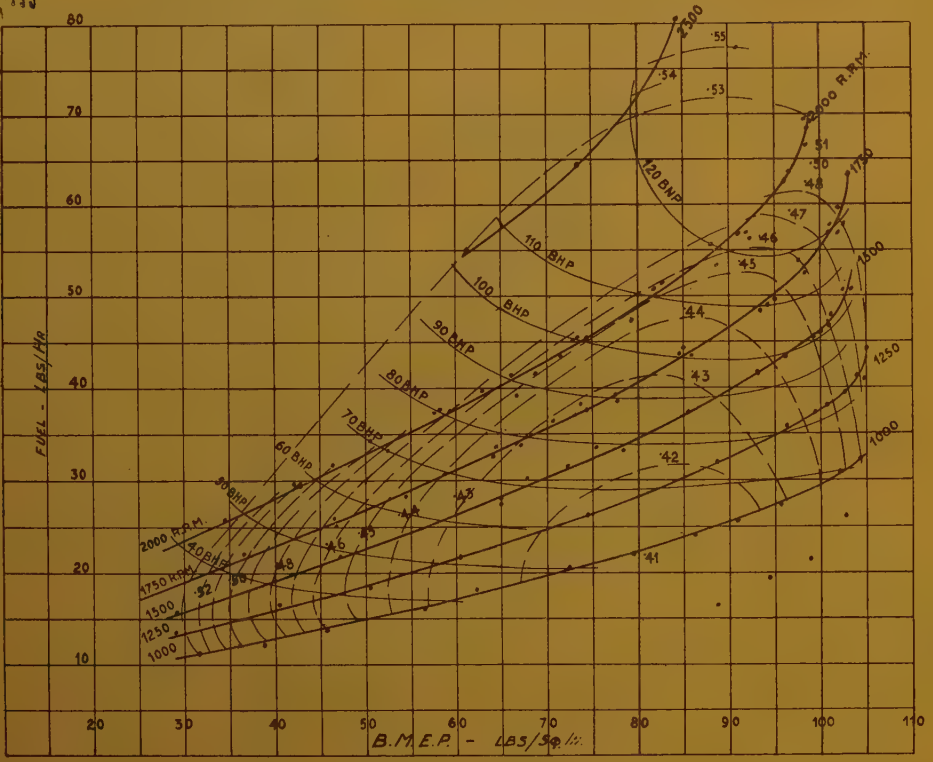


Fig. 18. — Power and consumption curves of model D. C. engines.

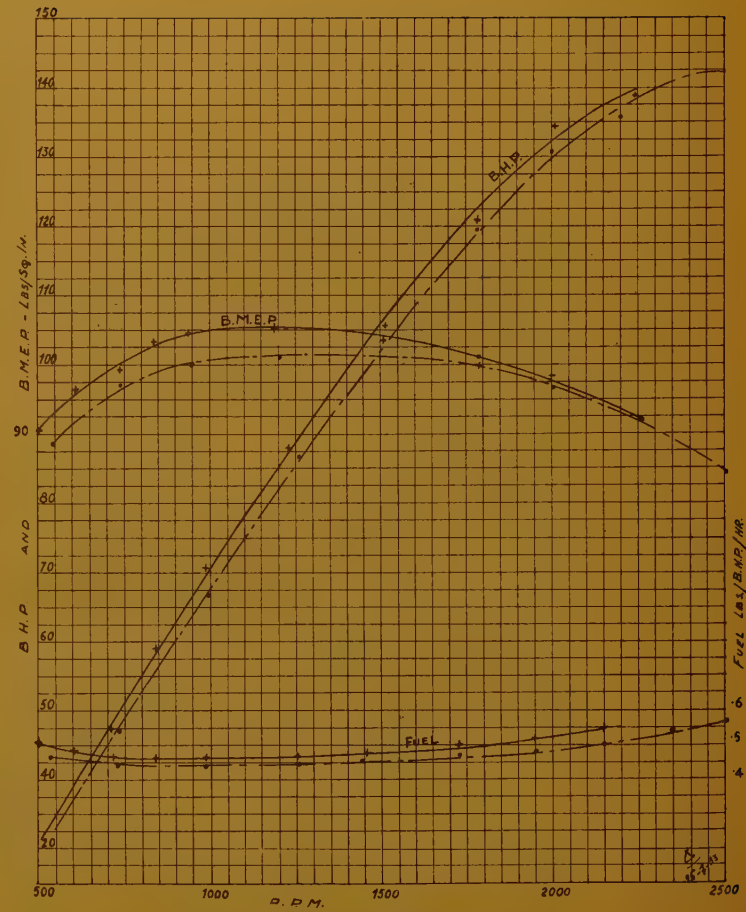
Great Northern Railway, Ireland.

Figs. 19 and 20.
Performance diagrams for 6-cylinder oil engine No. A 165-241
(Associated Equipment Co. Ltd.).



Figures on dotted lines are fuel consumptitons in pounds per B.H.P./hour.

Fig. 19.



Curves + Exhaust just visible, 600-2 250 r.p.m.
» ~ » clear at all speeds.

Fig. 20.

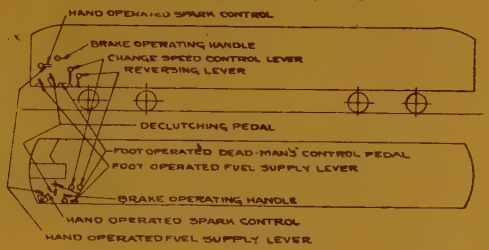
Pennsylvania Railroad.

Mechanical drive railcar.

Prime mover — 115 or 175-H.P. gasoline engine.

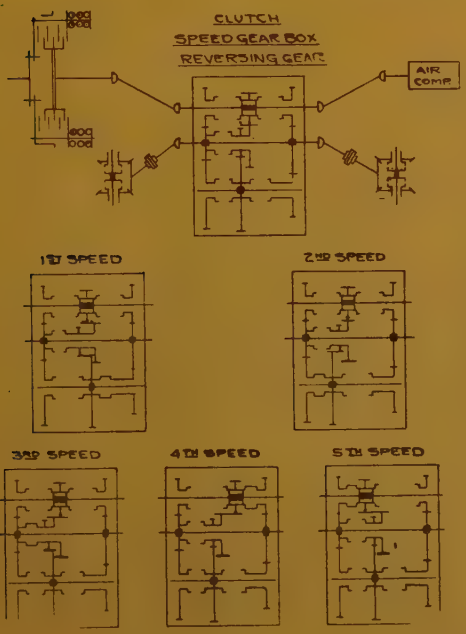
Diagram of transmission.

Diagram of control fittings.



Description.

The clutch is of the multiple disc dry plate type — steel and fibre composition.
Change speed gear: Selective sliding type.
Reversing gear: Bevel gear type with sliding clutch.
Transmission of power to axle: By propeller shafts and beveled gearing.
Joints used: Both metallic and fibre — universal joints.
Power transmitted by gears, jackshafts and propeller shafts.
Coasting possible with either transmission in neutral or clutch held disengaged.
No torque limiter provided.
Car can be driven in both directions.
The dead man's feature is incorporated in the air brake system: either brake handle must be held depressed with hand, or foot pedal held depressed with foot.
The dead man's safety device should come into action not later than 3 seconds after the moment the driver fails.
Control fittings provided in driver's compartment: Oil pressure gauge, engine speed tachometer, engine temperature gauge, battery charging ammeter, air pressure gauge. These meters are deemed indispensable but no advantage would result from self-recording units.



Description.

Clutch. — The clutch consists of 3 circular steel plates, called driven discs, splined to central hub. Plates are faced on each side with composition lining. The driving discs, in addition to the face of the flywheel, consist of 2 steel plates and an outer ring, slotted to engage bolts in the flywheel.

Twelve helical springs, parallel to the transmission shaft and equally spaced about the periphery of the driving discs apply pressure to the various plates in the engaged position of the clutch, transmitting the power of the engine to the transmission.

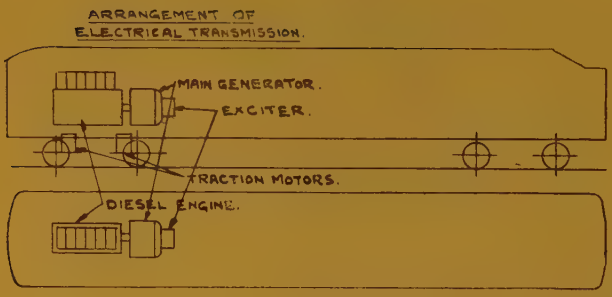
Speed gear box. — Consists of 5 forward speeds obtained by shifting gears with jaw type clutches machined in face perpendicular to driving face of gears. These clutches mate, when shifted, with similar jaws in face of driven gears. The gears are in mesh with mating gears at all times.

Reversing gear. — Located in each driving axle. Consists of 2 bevel gears with driving pinion from propeller shaft constantly in engagement with same. Suitable jaw type clutch, mounted on spline on driving axle in between ring gear may be engaged with either ring gear to give desired forward or backward motion. Simultaneous shifting in each axle is accomplished by interconnection of levers.

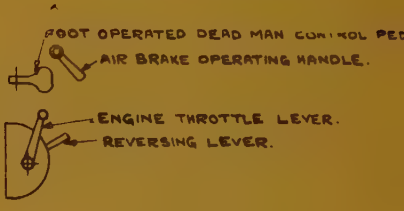
Fig. 21.

Pennsylvania Railroad.

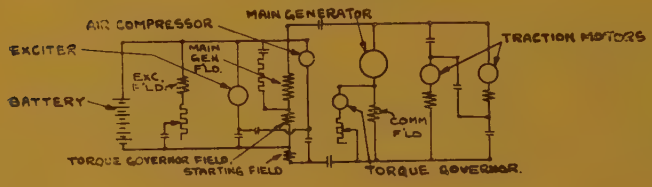
Electrical drive railcar.
Prime mover : 300-H.P. diesel engine.



Layout of driver's stand.



Fundamental wiring diagram.
Generator torque control. Westinghouse Electric and Manufacturing Co.



Description.

Number of diesel motors : One.
— generators : One main, one auxiliary.
— traction motors : Two.
Motor suspension : Hung on axle and nose spring supported on truck transom.
Coupling of diesel engine and generator : Direct — flange coupling.
Power for one motor may be cut off, but rotation is dependent on car speed.
Unused driver's compartment is locked.
Dead man's feature incorporated in air brake system. Either brake handle is held down with hand, or foot pedal held down with foot.
Maximum period which may elapse between the time the driver fails and that at which the dead man's device should act : 3 seconds.
Each driver's stand is provided with engine speed tachometer, engine temperature gauge, battery charging ammeter, air pressure gauges, voltmeter, ammeter. The front compartment is moreover provided with an oil pressure gauge and a kilowatt-hour meter.
Of these fittings, volt- and ammeter are deemed highly desirable, but dispensable; watt-hour meter dispensable. No advantage would be derived from self-recording units.
Battery charged from main generator at idling speed and from auxiliary generator at high speeds.
Engine is started from battery through special winding in generator.

Fig. 22.

g) *Mileages run by rail motor cars.*

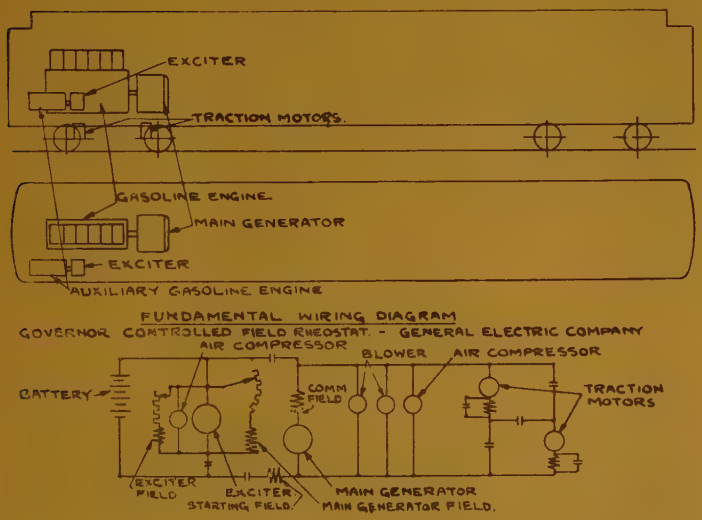
The mean daily mileage run varies between 100 and 150 miles with the exception of the 33-H.P. gasoline cars used on narrow-gage track of the Chosen Government Railways, which cover 74.5 miles per day. The mean yearly number of days out of service varies from 30 (Ceylon Government Railway)

Pennsylvania Railroad.

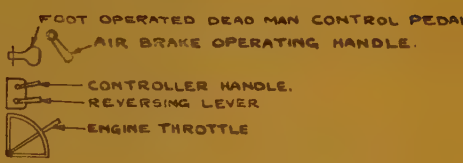
Electrical drive railcar.

Prime mover : 415-H.P. gasoline engine.

Arrangement of electrical transmission.



Layout of driver's stand.



Description.

Number of gasoline motors : One main, one auxiliary.
— generators : One main, one auxiliary.
— traction motors : Two.

Motor suspension : Hung on axle and nose spring supported on truck transom.

Flexible coupling between gasoline engine and generator.

Power for one motor can be cut off, but rotation is dependent on speed of car.

Unused driver's compartment is locked.

Dead man's feature incorporated in air brake system; either brake handle held down with hand, or foot pedal held down with foot.

Maximum period which should elapse between the time driver fails and that at which the dead man's device comes into action : 3 seconds.

In each compartment, the driver is provided with engine speed tachometer, engine temperature gauge, battery charging ammeter, air pressure gauges, voltmeter, ammeter. There is also an oil pressure gauge and a kilowatt-hour meter in the front driver's compartment. The voltmeter and ammeter are highly desirable, although dispensable. The watt-hour meter is dispensable. No advantage can be derived from making this fittings self-recording.

The battery is charged from the auxiliary generator.

The engine is started from the battery through a special winding in the generator.

Fig. 23.

to 69 (Reading Company) and 84 (Pennsylvania Railroad).

The overall speed is 20 m.p.h. (Ceylon Government Railway), 21 m.p.h. (Great Northern, of Ireland), 27.6 m.p.h. (Pennsylvania Railroad), 33 m.p.h. (Reading Company), 35 m.p.h. (Great Northern of Ireland). The corresponding numbers of stops per 100 miles run are : 85, 69, 22, 59 and 20 respectively.

h) *Railroads which have replied to the questionnaire, although operating but little if any rail motor equipment.*

The Delaware & Hudson Railroad	United States, America.
Long Island Railroad	United States, America.
New Zealand Government Railways	New Zealand.
The Rohilkund and Kumaon Railway Co., Ld.	India.
East Indian Railway	India.
South Indian Railway Co., Ld.	India.
Great Indian Peninsula Railway	India.
Bombay Baroda and Central India Railway Co.,	India.
North Western Railway	India.
The Bengal & North Western Railway, Co., Limited.	India.
Burma Railways	Burma.
Sudan Railways	Sudan.
Kenya and Uganda Railways and Harbours	Africa.
Ferro Carril del Sud	Argentina.
Ferro Carril Central Argentino.	Argentina.
Société Nationale de Chemins de Fer en Colombie	Colombia.
London Passenger Transport Board	England.
Cheshire Lines Committee	England.
Southern Railway	England.
Midland and Great Northern Joint Lines	England.

Some closing thoughts :

The term high-speed, like all comparative expressions, is relative. Prior to the advent of the automobile, railway train speeds, both passenger and freight, were very high as compared to all other forms of available land transport, hence railroads were able to render not only a very low cost service as compared to all other forms of available land transport but also to render a much higher speed service.

The development of modern highways and modern automotive highway equipment has very greatly reduced the speed advantage formerly held by the railroads, and to a lesser degree in some instances somewhat reduced the cost advantages which they formerly held.

It is this change in differential that has given rise to the effort to greatly increased speeds and at the same time reduce costs of rail passenger transport and to a lesser degree as yet of rail freight transport.

The growth of fast air transport as regards passenger mail and express service has also stimulated interest in the development of light-weight high-speed rail equipment for through handling.

It is essential from an economic standpoint that equipment designed for what we may today designate as high-speed service be of such a nature that it will be easy on the track, that it lend itsself to high-speed braking, that wreck and fire hazard be held to the lowest possible minimum and that travel comfort be an important factor in so far as passengers are concerned.

In this connection, it might be mentioned that experience indicates that the cost of track maintenance of lightly constructed branch lines is much lower when motorized equipment is used, also that higher speeds are permissible.

The advantages accruing from the light motorized switchers are just beginning to be appreciated in the United States and it is possible that their use may eventually become of some considerable importance.

It is felt by some that use of the « Merit and Demerit System » for disciplining those employees engaged in the maintenance and operation of rail motor equipment would aid much in the successful introduction of this new type of motive power wherever it is deemed advisable to use same.

In rail motor equipment as in the case of all other radically new developments, obsolescence is one of the most important factors involved when calculating service life and fixed charges, and should therefore be given due consideration.

It has been often suggested that if in the development of important new equipment some patent cross licence arrangement could be perfected, it would help much in expediting its perfection and use.

* * *

No attempt was made to include each and every manufacturer's or builder's equipment since it was felt sufficient to mention only typical types.

[621. 132. 3 (.436)]

Austrian Federal Railways 2-8-4 express locomotives (classes 114 and 214).

by J. NEBLINGER,

Ministerial Councillor,
Formerly Head of Department in the General Management of the Austrian Railways.

(Revue Générale des Chemins de fer).

The dismemberment of the former Austro-Hungarian Empire and the creation of new States profoundly modified the flow of traffic in Austria. Formerly, most of the passengers leaving Vienna travelled to the north or north-west and the bulk of the goods traffic followed suit. Today the resulting passport regulations and customs restrictions have caused the traffic to move to the west, so that the Vienna-Passau and Vienna-Salzburg lines have had to be adapted to the new state of affairs.

The express trains were formerly hauled by the most powerful passenger engines the Federal Railways possessed, namely the 2-6-4 engines of the 310 class and the 4-8-0 engines of the 113 class. These engines were built to haul 400 to 450-ton trains up gradients of 1 in 100 at 40 km. (25 miles) an hour. When, for the reasons given, the trains reached 500 to 550 tons weight, double heading became the usual practice. To avoid this and to increase the speed, the Federal Railways decided to design an engine for hauling their express trains which would meet the following requirements :

1. to haul 550 tons up continuous gradients of 1 in 100 at a constant speed of 60 km. (37.3 miles) an hour;

2. to be able to accelerate this train on the level from 60 to 90 km. (37.3 to 56 miles) an hour in 2 minutes, so as not to increase the time inevitably lost through the long gradients and many curves, by taking too long to regain speed;

3. to have a maximum speed of 110 km. (66.3 miles) an hour.

The preliminary calculations showed that the acceleration with a six-coupled engine would not be good enough between Vienna and Salzburg (314 km. = 194 miles, and 6 stops) whilst with an eight-coupled engine 1 hour could be saved on the run, which would be reduced to 4 hours 15 minutes.

The average speed would be 73.80 km. (45.9 miles) instead of 59.8 km. (37.2 miles) an hour without exceeding 100 km. (62 miles) an hour.

As the maximum axle load allowed is 18 t. (17.7 Engl. tons), three carrying pairs of wheels had to be provided making seven pairs of wheels in all. The 2-8-4 type was selected in preference to the 4-8-2 so as not to overload the trailing carrying axle and to get as deep a firebox as possible at the forward end.

It was also decided :

— not to exceed 15 kgr./cm² (213 lb. per sq. inch) pressure;

— to have a high superheat temperature;

— not to compound for simplicity;

— to exclude the use of four cylinders so as not to have to use a double cranked axle difficult and costly to make;

— to solve by experiment the question of using 2 or 3 cylinders and for this purpose to build one engine with 2 cylinders, and a second with 3;

— to try out two different trailing wheel arrangements. On locomotive No. 114-01, the two pairs of wheels are carried in a frame free to move about a centre in line with the leading pair of wheels, the centering gear being arranged in line with the trailing pair.

Fig. 1.

In the case of locomotive 214-01, the two pairs form an ordinary bogie free to move about the centre, with lateral play and centering gear;

— to combine the leading pair of wheels and the first pair of coupled wheels to form a bogie of the Krauss-Helmholtz type;

— finally to make the largest possible number of parts common to both engines.

In accordance with this programme and these decisions, one 3-cylinder locomotive, class 114, with trailing truck, was ordered from the Wiener-Neustadt works, and one 2-cylinder locomotive, series 214, with trailing bogie, from the Floridsdorf shops.

In this note, the 3-cylinder locomotive will be described briefly and the points in which it differs from the 2-cylinder locomotive will be pointed out so that the results of the comparative trials can be appreciated.

I. — Description of the 3-cylinder locomotive.

(fig. 1).

Boiler and boiler fittings. — The wide *outer firebox* shell is made of mild steel. The casing is in one piece reinforced in line with the cross stays and outer rows of roof stays.

The *inner firebox* is copper. Hollow copper stays are used between the side plates. A brick arch is fitted.

The *barrel* is in two rings. The inside diameter of the back ring is 1.919 m. (6 ft. 3 9/16 in.) and that of the front ring 1.96 m. (6 ft. 5 3/16 in.).

There are 189 tubes 6 m. (19 ft. 8 1/4 in.) long. The 38 flue tubes are 135 mm. (5 5/16 inches) inside diameter and contain the Schmidt superheater elements connecting the two compartments of a cast steel header in the smoke box. The other 151 tubes have an inside diameter of 51.5 mm. (2 inches).

A Dabeg feed-water heater is fitted and automatically maintains the boiler water level. Two Friedmann non-lifting injectors are also fitted.

Two gauge glasses are fitted and this has made it possible to suppress the gauge cocks.

A Zara type regulator is fitted.

The boiler centre line is 3.40 m. (11 ft. 2 in.) above rail level, so that the water level is over 2 m. (6 ft. 6 3/4 in.) above the cab foot plate. Most of the auxiliaries take their steam from a collector, the shut-off valves being conveniently arranged for the driver.

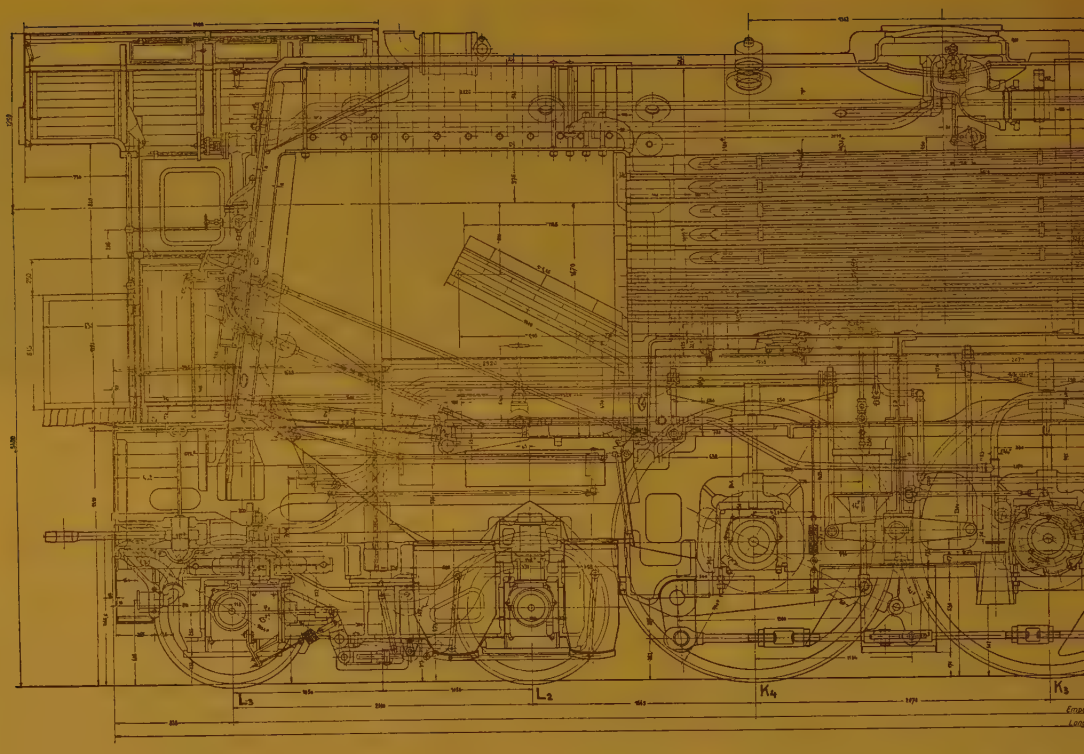
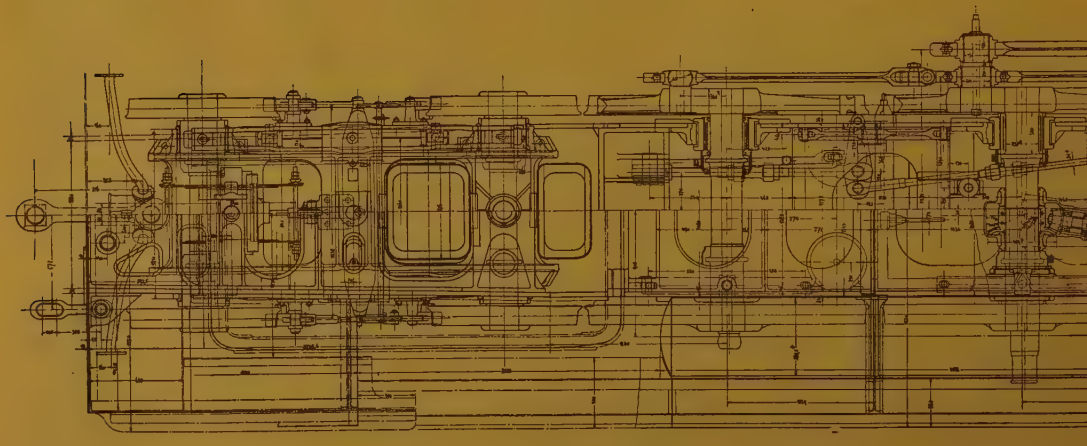


Fig. 2. — Longitudinal



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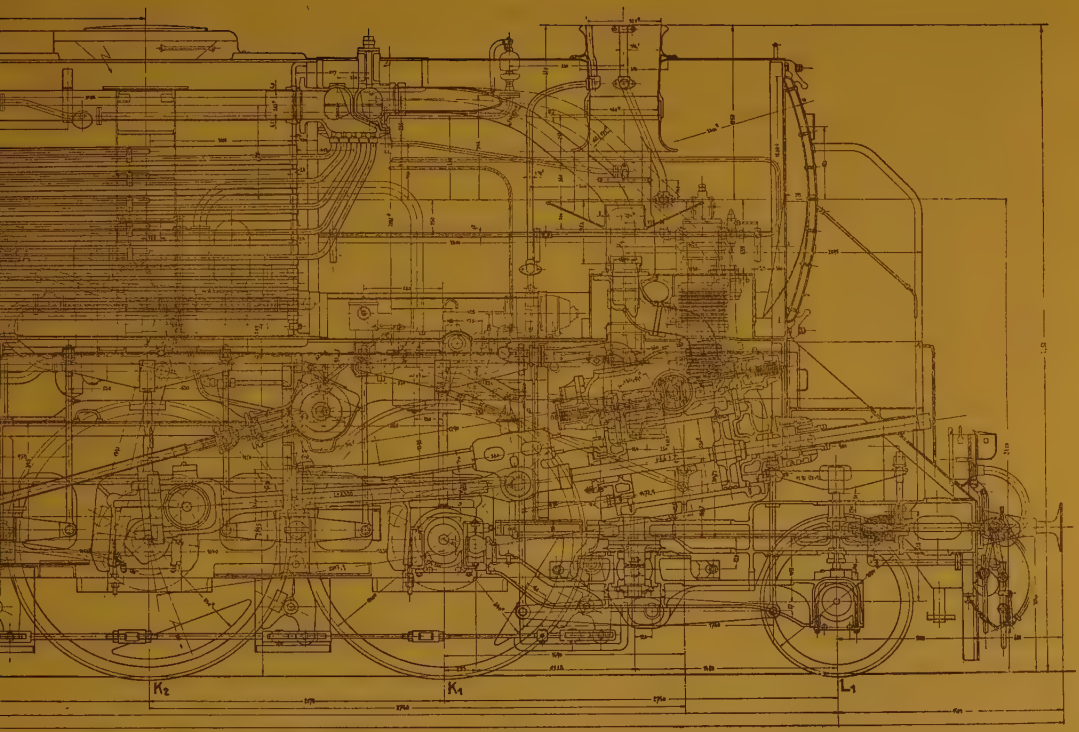
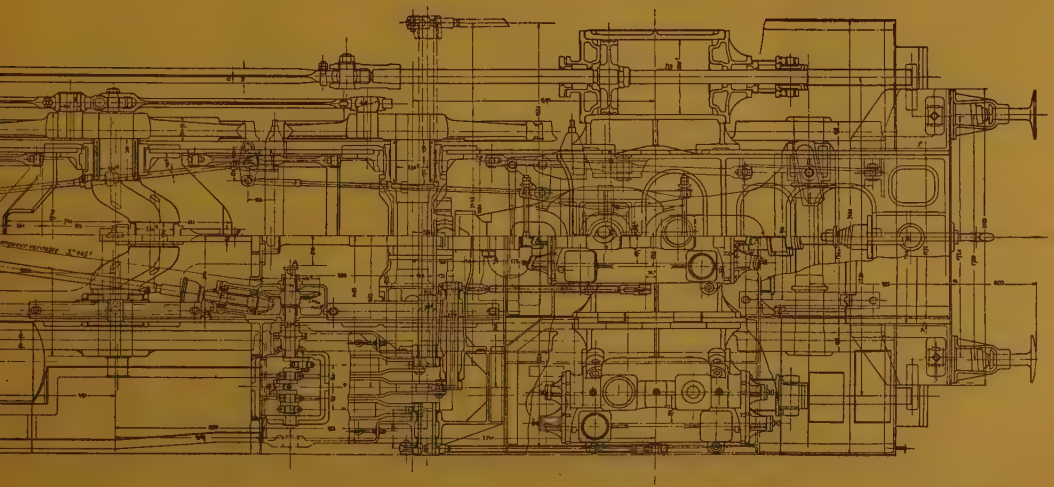


f a 114 class locomotive.



Actual length.

A Friedmann ejector supplies water for spraying the smoke box, the ashpan, and the coal on the tender.

Three Friedmann blow down valves are fitted, one on each side of the firebox above the foundation ring, and the third under the barrel. The blow down pipes are brought into a single separator where the energy of the water is so dispersed that when blowing out it is quite unnecessary to use a pit.

The *grate,* 4.72 m² (50.6 sq. feet) in area, consists of three rows of bars, the middle carried on a frame being arranged to drop.

The ashpan is in three sections, one under the grate inside the frames and the others under the part of the grate outside the frames. All three are fitted with doors for admitting air and cleaning out the ashes.

The *smokebox* is 3.435 m. (11 ft. 3 in.) from the tube plate to the front plate. The door is held tight by 13 clips. A man-hole behind the chimney gives access to the superheater. The smokebox bottom rests on a saddle made of steel plate, open underneath, to give access to the steam chest admission and exhaust pipe joints of the middle cylinder and the joints where these pipes pass through the smoke box itself; the tightness of these joints can thus be easily ascertained.

The chimney is in two parts which can slide one in the other, so that the height can be adjusted. The chimney extends some 640 mm. (2 ft. 1 1/4 inches) inside the smoke box and is fitted with a Langer system spark arrestor. As the chimney only protrudes 240 mm. (9 7/16 inches) out of the smoke box, side screens have been fitted to lift the smoke and so prevent it interfering with the driver's look out.

Frame, bogie and truck.

The frame is built up of two steel frame plates 34 mm. (1 11/32 inches) thick, strongly cross braced at the leading and trailing ends by the buffer beams made of plate 15 and 10 mm. (19/32 inch and 25/64 inch.) thick respectively and by many cross stays, most of them cast steel. The box stay across the frames in line with the outside cylinders which it keeps in position is a casting; it also forms the leading end drag box. The slide bar stays of the left hand and middle cylinders are also cast steel (the right hand slide bars are carried by a separate bracket), as are the brake shaft brackets, the firebox cross stay, the truck centre, the truck centering gear, the firebox back stay, and the trailing drag box. The frame is further braced by the vertical plates carrying the boiler, and by being plated across both top and bottom between the last three pairs of drivers.

The leading truck is combined with the leading pair of drivers to form a Krauss-Helmholtz bogie for guiding the engine. The side play of the leading pair of coupled wheels is 30 mm. (1 3/16 inches) in both directions.

A detailed description of the trailing truck is not called for. Unlike the usual Austrian practice as regards bogie vehicles, the bogie frame is a single-piece steel casting carried on the four axle boxes on balls. It has powerful side springs the buckles of which are extended to form spherical bearings for the main frame.

Coupled wheels. — Axle boxes. — The inside cylinder drives the second pair of coupled wheels, and the outside cylinder the third pair. The crank axle (second pair of coupled wheels) is 5 % nickel steel.

All the axles are hollow. The wheel centres are cast steel.

The counterbalance weights have been calculated to balance the revolving masses and also the reciprocating parts with still a slight excess. The locomotive has, therefore, very little vertical movement and practically speaking has no hunting movement.

As stated above, the leading pair of drivers has 30 mm. (1 3/16 inches) side play on each side of the centre line. The fourth pair of coupled wheels has 20 mm. (25/32 inch) play on each side. The second and third pairs of coupled wheels have no side play, but the flanges of the third pair have been reduced in thickness by 10 mm. (25/64 inch).

The axle boxes of the second and third pair of drivers are of the Obergethmann type with bearings in three parts, bearing on about 5/6th of the journal circumference. The other axle boxes are of the usual type.

The clearance volume is about 10 % of the swept cylinder volume.

Motion. — The piston heads, all three to the same pattern, are steel forgings. The outside piston rods and tail rods are hollow.

Each piston is fitted with three piston rings in three separate grooves. Brass rubbing strips 1.5 mm. (1/16 inch) thick and 190 mm. (7 1/2 inches) long are fitted in the two outer grooves to prevent the piston heads themselves rubbing on the cylinders, should the cross head slippers and the tail rod guides wear excessively.

The single slipper of the cast steel cross heads is lined with bronze and white-metalled, and is 580 mm. (22 13/16 inches) long in the case of the middle cross head, and 460 mm. (18 1/8 inches) in the others. The knuckle pins are fitted with spherical bushes over which the brasses, spherical too, of the little ends fit.

The outside connecting rods, 4 m. (13 ft. 1 1/2 in.) long, are made of nickel manganese steel. The inside rod is only 2.33 m. (7 ft. 7 3/4 in.) long and has a forked big end.

The set of coupling rods on each side has four ends, the outer ones being solid and fitted with spherical brasses, and two horizontal knuckle joints combined with vertical ones. The big end on the driving coupling rod pin is fitted with two cotters so that the intermediate coupling rod can be set to the exact length.

The outside driving crank pins are at 120°. Owing to the inclination of the inside cylinder, the driving crank pin is set slightly back so as to be at 128° 37' with the right hand, and 111° 23' with the left hand crank pin.

Valve gear. — An improved Lentz poppet valve gear is fitted with which the valves are opened and closed very quickly and without shock. The valves are actuated by a mechanism of the Marshall type, having a cross shaft driven at the same angular speed as the driving axles. This shaft is driven by bevel gears and cardan shaft off the third pair of coupled wheels. This shaft has three cranks, one per cylinder, at the same angles as the cranks. Each of the cranks imparts an oscillating motion to a rod, the amount of movement being varied with the cut-off. The rods in turn drive the cam shaft which operates the poppet valves. The steam valves are 180 mm. (7 3/32 inches) and the exhaust valves 200 mm. (7 7/8 inches) in diameter. The valves are kept on their seats by helical springs fitted outside the steam chests.

Drifting device. — Above each steam chest is fitted a small vertical cylinder in which a piston moves, which is automatically lifted by compressed air admitted to it when the regulator is shut, and which lifts the two steam valves and the two exhaust valves of the corresponding cylinder, in which the pressure is thus equalized.

On re-opening the regulator the steam acts on the said piston and drives it down. The poppet valves are then released and function in the normal way.

Brakes. — The locomotive is fitted with :

1. The Knorr compressed air brake for

braking the engine, tender and train stock.

All wheels of the engine except the leading pair are braked. Two vertical 355-mm. (14 inches) cylinders are fitted between the main frames between the third and fourth pairs of drivers. Each of these cylinders operates the brake rigging through a separate cranked lever. To equalise the pull of the two cylinders, the first brake cross bar carries the cross compensating gear needed. A third cylinder, 330 mm. (13 inches) in diameter, brakes the trailing bogie. 71 % of the engine weight in working order is thus braked.

2. A supplementary Knorr brake on the coupled wheels, when used, brings the braked weight up to 97 %.

3. The automatic vacuum brake on the tender and rolling stock, as part of the Austrian express trains are still fitted with the vacuum brake.

These compressed-air and vacuum brakes are combined so that the vacuum brake can be applied on the train and the air brake on the engine at the same time, and inversely.

Lubrication. — The axle boxes and frame pins are lubricated by a Friedmann lubricator pump of 8.5 litres (1.87 Br. gallons) capacity with 10 double feeds, and the cylinders and valves by two 6-litre (1.32 gallons) pumps of the same make, with 20 feeds. All the delivery pipes are copper and are fitted with Friedmann ball-type non return valves.

In addition, 9 Friedmann sight-feed lubricators are carried on the boiler barrel and feed oil to the axle box guides and to various pins. If desired, they are used as a standby axle-box lubrication arrangement, some cocks being operated for this purpose.

A number of oil wells, which the driver fills, are fitted as usual close up against the parts to be oiled.

Sanding gear. — The sand box is carried on top of the barrel. The leading side of all coupled wheels is sanded by Borsig compressed air sanders.

Lighting. — The head lamps and all lamps in the cab are electric, current being supplied by a 500-watt self-regulating turbo-generator. The main circuit from the generator to the cab has two 20-ampere fuses and each individual circuit two 10-ampere fuses.

Speed indicator. — A Teloc speed indicator is fitted in the cab and is driven from the right hand trailing wheel of the truck.

II. — Main differences between locomotives 214-01 and 114-01.

(fig. 4).

Frame and trailing bogie. — The 214-01 locomotive has frame plates 32 mm. (1 1/4 inches) thick instead of 34 mm. (1 3/8 inches). The frame is cross stayed by box castings and stays which differ from those on the 3-cylinder locomotive in shape and layout, but give the more strength to the frame.

The truck of locomotive 114-01 is replaced on locomotive 214-01 by a trailing bogie with its centre carried by a cast steel frame stay. This centre is given side play which is controlled by laminated springs with an initial tension of 2.5 tons.

Coupled axles. — The counter-balance weights on the driving coupled wheels counter-balance 17 1/2 % of the reciprocating parts.

The first pair of coupled wheels has 30 mm. (1 3/16 inches) side play. The other three pairs have no side play, but the third pair (second driving pair) has had the flanges reduced in thickness by 10 mm. (25/64 inch).

Cylinders. — The diameter is 650 mm. (25 5/8 inches). The back covers are cast hollow and support the slide bars at their leading end.

Motion. — The pistons, cast in special steel, are hollow. Three thin rings are fitted. The rods and tail rods are hollow. The cross heads are also cast steel of special quality.

The connecting rods are forged from special steel. The two ends are solid. The large end is fitted with brasses which can be adjusted about the centre line normal to those through the rod and the crank pin. The little end bearings are spherical. In this way any difficulties can be avoided, which an oblique position of the driving axle relatively to the transverse centre line through the middle of the two cylinders — arising from the play of the bearing springs or unequal tightening up of the axle box wedges — might set up. When the magnitude of the forces transmitted and the length of the driving crank pin (218 mm. = 8 19/32 inches) are appreciated, the possibility of trouble will be the better realised.

The leading coupling rods have a double knuckle in the horizontal and vertical planes. As the fourth pair of coupled wheels has no side play the trailing side rods are connected to the middle rods by a simple horizontal knuckle joint.

Valve gear. — The Lentz type steam and exhaust valves are driven by a cam shaft receiving its oscillating motion from a Walschaerts gear.

Leading dimensions of the 114-01 and 214-01 locomotives.

	Locomotive 114-01.	Locomotive 214-01.
Grate area	4.72 m² *(50.80 sq. ft.)*	4.72 m² *(50.80 sq. ft.)*
Firebox heating surface	18.70 m² *(201.28 sq. ft.)*	18.70 m² *(201.28 sq. ft.)*
Tube heating surface	264.50 m² *(2847 sq. ft.)*	264.50 m² *(2847 sq. ft.)*
Total evaporative heating surface	283.2 m² *(3048.3 sq. ft.)*	283.2 m² *(3048.3 sq. ft.)*
Superheating surface	77.8 m² *(837.4 sq. ft.)*	77.8 m² *(837.4 sq. ft.)*
Boiler pressure	15 kgr./cm² *(213.3 lb. per sq. inch.)*	15 kgr./cm² *(213.3 lb. per sq. inch.)*
Diameter of driving wheels with 50-mm. (2″) tyres	1.900 m. *(6 ft. 2 25/32 in.)*	1.900 m. *(6 ft. 2 25/32 in.)*
Diameter of carrying wheels with 50-mm. (2″) tyres	0.994 m. *(3 ft. 3 1/8 in.)*	994 m. *(3 ft. 3 1/8 in.)*
Cylinder { diameter	530 mm. *(20 7/8 in.)*	650 mm. *(25 5/8 in.)*
Cylinder { stroke	720 mm. *(28 3/8 in.)*	720 mm. *(28 3/8 in.)*
Rigid wheel base	2.070 m. *(6 ft. 33/64 in.)*	4.140 m. *(13 ft. 7 in.)*
Total wheel base	12.635 m. *(41 ft. 5 7/16 in.)*	12.635 m. *(41 ft. 5 7/16 in.)*
Distance between bogie centres	9.115 m. *(29 ft. 11 in.)*	10.165 m. *(33 ft. 13/64 in.)*
Length (over buffers-over fenders)	15.073 m. *(49 ft. 7/16 in.)*	15.040 m. *(49 ft. 4 5/32 in.)*
Maximum speed allowed	100 km./h. *(62 miles/h.)*	100 km./h. *(62 miles/h.)*
Weight empty with 70-mm. (2 3/4″) tyres	108.3 t. *(106.6 Engl. tons)*	106.8 t. *(105.1 Engl. tons)*
Weight in running order	118.7 t. *(116.8 Engl. tons)*	118 t. *(116.1 Engl. tons)*

Fig. 4.

The steam valves are 180 mm. (7 3/32 inches) and the exhaust 230 mm. (9 1/16 inches) in diameter. The design is such that the clearance volume has been reduced to 6 %.

Small cylinders have been fitted above the steam chests. The pistons in these cylinders are held up by compressed air as long as the regulator is open; they are driven down when the regulator is shut and hold the two steam valves of each cylinder off their seats. Although the exhaust valves are not affected by the auxiliary pistons coming down, perfectly rectilineal diagrams are obtained, even at very high speeds, when running with the regulator shut.

Brakes. — The two 305-mm. (12 inches) brake cylinders operate the brake rigging through a common brake shaft and with the 330-mm. (13 inches) bogie brake cylinder, as fitted on the bissel truck of locomotive 114-01, makes it possible to brake about 70 % of the weight of the locomotive 214-01.

By the supplementary Knorr brake, the percentage can be raised to about 98.

III. — Results of trials with the 114-01 and 214-01 engines.

To reduce the cost of making the trials, the engines were used to haul, on several occasions and in succession, a regular express train between Vienna and Linz, a distance of 189 km. (117.4 miles) with only two stops. A dynamometer car was used.

Indicator diagrams were taken at short intervals and, at each change in the way the engine was worked, a note was made of the boiler pressure, steam chest pressure, superheat temperature, feed water temperature, temperature of the waste gases, and finally of the smoke box vacua.

The dynamometer car recorded the tender drawbar horse power, the speed, the steam used for train-heating, the composition of the smoke box gases, and the working of the brakes.

Preliminary tests had been carried out to find the coal consumption for maintaining the boiler pressure when running with the regulator shut, for the

brake, for heating the train, and finally for producing the heat wasted by the feed overflow.

The tender was fitted with water level gauges at the four corners.

One of the test trains weighing 552 t. (543 Engl. tons) ran at the average speed of 75 to 84 km. (46.6 to 52.2 miles) an hour. This was the tonnage and speed specified. Another train of 672 t. (661.4 Engl. tons) covered the distance at an average speed of 70 km. (43.5 miles) an hour.

The average boiler pressure was 13.5 kgr. (192 lb. per sq. inch) and the temperature of the steam 316° C. (600.8° F.).

With the 672-t. train, locomotive 214-01 developed 4 115 I. H. P. and 2 827 drawbar horse power under unfavourable weather conditions.

For equal work the coal and water consumption was the same with the two engines, and so were the thermal efficiencies.

The mechanical efficiencies differed. The resistance of the 3-cylinder locomotive was definitely greater than that of the 2-cylinder engine. The overall efficiency of the 3-cylinder engine, usually 5 to 5.5 %, only occasionally touched 6 %, whereas the usual efficiency of the 2-cylinder engine was 5.6 to 6.97 %.

This means that for the same drawbar horse power that the 3-cylinder engine used 6 % more fuel.

Against this, the trailing truck of the 3-cylinder engine showed itself so much better than the trailing bogie under the other engine that all 214-01 engines since built have been fitted with it.

As a result of these trials the Austrian Federal Railways have now seven 214 class engines, six with trailing trucks, whilst engine 114-01 remains the only one of its type.

[621. 13 (.44), 621. 335 (.44) & 625. 2 (.44)]

Rolling stock improvements made by the French Main-Line Railways since the war.

(From the *Revue Générale des chemins de fer.*)

General.

Before dealing with the rolling stock itself, we should endeavour to form a correct idea of its importance by briefly reviewing the other related railway factors.

These railways own 42 050 km. of lines with an invested capital of 65 476 854 100 fr. and employ over 460 000 people. The traffic statistics in 1932, a crisis year, were :

Total operating receipts.	12 265 891 648 fr.	
Goods receipts (slow goods only) . .	7 616 860 693 fr.	
Passenger receipts (including express goods)	4 433 990 278 fr.	
Tonne-kilometres (Engl. ton-miles) (slow goods only)	32 383 405 593	(19 804 719 300).
Passenger-kilometres (passenger-miles)	25 546 363 126	(15 874 050 300).

TABLE 1.

	ALSACE-LORRAINE		EST		STATE		MIDI		NORD		P. L. M.		P. O.		ALL RAILWAYS (5)	
	1918 (1)	1932	1913	1932	1913	1932	1913	1932	1913	1932	1913	1932	1913	1932	1913	1932
Steam :																
Locomotives	1 624	1 567	1 899	2 507	2 837	3 562	1 058	1 079	2 333	2 752	3 560	5 560	2 040	2 323	15 351	19 350
Rail motor coaches	"	"	"	2	2	"	"	"	11	10	18	4	11	11	42	27
Electric :																
Locomotives	"	"	"	"	9	39	3 (2)	314 (3)	"	"	"	37	13	218	25	608
Rail motor coaches	"	"	"	"	49	251	30 (2)	57 (4)	"	"	"	"	7	82	86	390
Intern. combustion-engined:																
Locomotives	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	" (6)
Locotractors	"	1	"	"	"	37	"	"	"	9	"	92	"	3	"	142
Rail motor coaches	"	2	"	"	"	24	"	1	"	2	"	2	"	2	"	33
Carriages and passenger brake vans	3 329	3 835	6 610	9 158	4 989	8 301	4 805	7 020	7 732	10 040	10 289	11 845	6 149	5 489	43 903	55 688
Wagons and goods brake vans	35 087	48 804	56 418	77 972	43 397	76 743	28 139	29 419	77 763	87 512	100 090	140 628	44 521	58 492	385 415	519 270

(1) Stock at 31 Dec. 1918. — (2) Single-phase current. — (3) Of which 1 single-phase. — (4) Of which 11 single-phase. — (5) Excluding the Ceinture Railway which owns 160 steam locomotives. — (6) Since then, the Paris-Lyons-Mediterranean has put into service 2 diesel-electric locomotives, and the Ceinture Railway one.

As regards the rolling stock, to end these general remarks, the line of development has been to strengthen it [greater power, general use of steel, strengthened drawgear (70 tons), etc...] and to make it suitable for higher speeds (continuous brake fitted to all stock).

The standard gauge stock position is as shown in table 1, the 1913 figures being given for comparison.

Steam locomotives.

As a rule, locomotive development has been on the lines of greater power or, for equal power, reduced fuel consumption.

This change is mainly the result of the great increase in train weight. Between 1913 and 1932 the average weight of passenger trains has grown from 150 to 250 tons, and that of goods trains from 450 to 900 tons. Many long-distance goods trains exceed 2 000 tons.

The following figures show how the power of the locomotives has been increased to meet this growth. In 1913, the draw-bar horse power was about 1 500; by 1932 it had become 3 000 in some cases.

The simultaneous reduction of the coal consumption and increase in power should be noted. On the Paris-Lyons-Mediterranean, for example, the passenger engines consumed 6.1 kgr. per 100 tkm. (22.0 lb. per 100 Engl. ton-miles) in 1932, as compared with 6.6 kgr. (23.8 lb.) in 1913.

The necessary transformation of the steam locomotive has been effected by improving the types in service and by introducing new designs.

Improvement of existing locomotive types.

Many important improvements have been carried out on existing locomotives since the war. Each railway has played its particular part in this work, but all

have made use of most of the improvements mentioned below.

Improvements intended to increase the power and to reduce fuel consumption. — Compounding must be placed first, as although used in pre-war times it has been still further developed on some railways since the war.

Superheating, applied before the war, has been improved ever since. The actual degree of superheat has been increased as far as the metal in the superheater elements, the cast iron of the cylinders, and the lubricating oils would allow.

Thus, the steam temperature has been raised to about 400° C. (752° F.). The use of superheating has become very general as table 2 shows.

TABLE 2. — **Locomotives fitted with superheaters.**

		Alsace-Lorraine. (1)	Est.	State.	Midi.	Nord.	P. L. M.	P. O.	All Railways.
Number of steam locomotives	1913.	1 624	1 899	2 837	1 058	2 333	3 560	2 040	15 351
	1932.	1 567	2 507	3 562	1 079	2 752	5 660	2 323	19 450
Number of locomotives with superheaters	1913.	434	379	186	89	321	198	398	2 005
	1932.	866	2 013	1 792	385	1 443	3 805	1 283	11 587
Number of locomotives built since 1918 with superheaters		138	471	580	67	387	2 593	741	4 977
Number of other locomotives fitted with superheaters since 1918		80	445	4	—	79	818	75	1 501

(1) In the case of this railway, the figures given are those on the 31st December, 1918, instead of on the 31st December, 1913.

Feed water heating is a more definitely post-war improvement on the French railways, and whether obtained by using the combustion gases, or more frequently the exhaust steam, has shown very good results. The consequent wide use of this equipment is shown in table 3 hereafter.

TABLE 3. — **Locomotives fitted with feed water heaters.**

		Alsace-Lorraine.	Est.	State.	Midi.	Nord.	P. L. M.	P. O.	All Railways.
Number fitted with feed water heaters	1913.	292 (1)				42	1		335
	1932.	899	230	665	81	422	1 157	129	3 583

(1) The position as at the 31st December, 1918, has been taken instead of at the 31st December, 1913.

Raising the boiler pressure from 16 to 20 kgr./cm² (228 to 284 lb.) has been one of the most marked changes in practice in recent years.

Then too, very careful investigations have been made into the exhaust and have resulted in a considerable increase in the draught with a substantial reduc-

tion in back pressure. The result on certain engines has been to raise the evaporative capacity by 50 %.

Amongst other important improvements are those which have increased the engine efficiency by better valve events and by reducing the losses in the steam passages (use of long-stroke valves, double-ported valves and oscillating or rotating cam-operated poppet valves).

Finally, the greater use of firebox arch tubes which, crossing the firebox longitudinally, improve the circulation of the water between the front and back ends, etc., should be mentioned.

Improvements in running conditions, in the general handling of the engines, and in reducing costs as well as in safety. — This heading includes, among many others, the following improvements :

Side screens fitted at the front end of high-speed locomotives to prevent smoke beating down onto the cab;

Extended use of signal repeating devices, vigilance levers, etc.;

Electric cab lighting;

Self counter-balancing of the webs of the crank axles on high-speed locomotives;

Mechanical lubrication of the valves and pistons by improved equipment giving better oil diffusion;

Pressure lubrication of coupled axle journals;

Use of felt pads in big end bearings to distribute the oil all along the crank pins.

Use of feed water softeners on boilers.

Examples of results obtained on some of the railways. — The Paris-Orleans, in particular, has devoted much attention to improving existing designs. The extension of its electrified lines has made it unnecessary to order new locomotives, as it increased the number of locomotives available for service.

The Company raised the efficiency of the steam engine by reducing losses due to wire drawing through the steam passages, by improving the exhaust and the valve gear.

The proportions of the steam passages both through the passages properly speaking and through the ports have been radically altered. The usual ratio between piston area and the steam passages trough the valve between 10 and 12 has been brought down to 6 and even 5.

The alteration meant that the sections of the steam passages were doubled and therefore the losses between the boiler and the exhaust were one quarter.

The engines altered were fitted with a double exhaust and the Kylala petticoat, as thereby the back pressure on the pistons is halved, and the boiler can be worked efficiently at rates not previously used [smoke box vacuum as high as 300 to 400 mm. (11.8 to 15.7 inches) of water].

These alterations went with the increase in superheat [temperature raised from 300 to 400° C. (572 to 752° F.) at a pressure of 16 to 17 Hpz. (227 to 242 lb. per sq. inch), and with the necessary correlative improvements in the accessory parts.

In this way, a new locomotive was produced which developed, at the same hp cut-offs, 40 to 55 % greater power, this increase rising with the speed, and reaching about 85 % at 110 km. (68.3 miles) an hour.

As regards the thermal efficiency of the engine, for a given drawbar horse power and speed, the saving in water was 21 % to 37 %, according to the power and speed considered, and in coal, 33 to 61 %, the saving being the greater the higher the speed considered.

The maximum indicated horse power developed increased from 2 100 H.P. for the ordinary engine to 3 400 H.P. for the improved locomotive.

The same Company decided to improve on the same lines its other super-

heated Pacific type locomotives by fitting an improved superheater without changing the tube plates, and a Kylchap blast pipe, and by replacing the lp cylinders by cylinders with double admission and double exhaust slide valves. The engines which had already been fitted with new lp cylinders with ordinary piston valves were improved by making the ports 75 mm. (2 61/64) instead of 60 mm. (2 23/64 in.) long and by improving the superheater and blast pipe, as on the other altered engines. The maximum indicated horse power of these engines was thus increased to 2 700 and 2 500 respectively.

The improvements introduced on the Paris-Lyons-Mediterranean Railway in particular resulted in the class 231 F *Pacific* engines with 18.2 Engl. tons on each coupled pair of wheels, 20 kgr./cm² (284 lb. per sq. inch) boiler pressure, 4.25 m² (45.7 sq. feet) grate area and an economiser. The hp cylinders are 440 × 650 mm. (15.5/16 in. × 25 5/8 in.) and the lp 650 × 660 mm. (25 5/8 in. × 26 in). Piston valves are used; a double blast has been fitted. The driving wheels are 2 m. (6 ft. 6 3/4 in.) in diameter. The substained drawbar horse power obtained is 2 200. The engine hauls in ordinary service 550 tons up 1 in 125 gradients at 95 km. (59 miles) an hour.

New locomotives types.

As mentioned above, the Railways have transformed the steam locomotive not only by improving existing engines, but also by building new designs incorporating most of the improvements made to the old designs.

The following further improvements have been adopted :

— general use of autogenous welding and in particular the manufacture of copper and steel fireboxes autogenously welded throughout;

— use of special steels and special metals, especially for lightening motion parts;

— reduction of types of parts by standardisation of similar parts used on different classes of engines.

The new passenger engines are usually eight-coupled, and the goods, ten-coupled.

High-speed locomotives. — The table below gives the leading dimensions of express locomotives being built by the Companies. The tenders on the French Est 4-8-2 engines carry 8 tons of coal and 35 m² (7 700 Br. gallons) of water, to be able to run non-stop the 353 km. (219.3 miles) between Paris and Nancy or 277 km. (172 miles) between Troyes and Belfort.

These engines work at the following hourly speeds :

on the level. . . .	120 km. (75 miles)	with loads of	650 t. (640 Engl. tons),
on 1 in 166 gradients.	95 km. (59 miles)	» »	450 t. (443 Engl. tons),
on 1 in 125 gradients.	90 km. (56 miles)	» »	400 t. (394 Engl. tons).

The Paris-Lyons-Mediterranean 4-8-2 C1 class engines have given a continuous I. H. P. of 3 500 and a drawbar horse power of 2 500.

This engine is able to haul easily, in normal working, 630 t. (620 Engl. tons) up gradients of 1 in 125 at 100 km. (62 miles) an hour. The coal consumption varies between 0.6 and 0.8 kgr. (1.32 and 1.76 lb.) per indicated H.P.-hour and 0.8 to 1.5 kgr. (1.76 and 3.30 lb.) per effective H.P.-hour according to the speed and power.

The Paris-Lyons-Mediterranean has also put into service a number of *Mountain* type locomotives with 1.79-m. (5 ft. 10 1/2 in.) diameter wheels for working heavy trains with frequent stops over the difficult sections of its main lines.

The Nord *Superpacifics* class 3-1251 to 3-1290 were designed to haul 500, 600-t. (492, 590 Engl. tons) and even

Fig. 1. — French State Railways 4-8-2 locomotive, designed by the O. C. E. M.

Fig. 2. — Alsace-Lorraine Railways 4-6-2 locomotive, designed by the O. C. E. M.

TABLE 4. — **Leading dimensions of high-speed locomotives.**

RAILWAY.	A. L.	EST (2)	STATE	NORD	P. L. M.		P. O.
TYPE.	4-6-2	4-8-2	4-8-2	4-6-2	4-6-2	4-8-2	4-8-0
CLASS.	S. 16	241-001-241-041.	241-101	3-1251-3-1290	231-G.	241-C	4701
System (simple or compound) . .	SE	C	SE	C	C	C	C
Type of superheater	CS	DM	Schmidt	Schmidt	Schmidt	Schmidt	Houlet
Type of feed water heater . . .	ACFI	Metcalfe	ACFI	ACFI	ACFI / Dabeg	ACFI	ACFI
Boiler pressure . . . kgr./cm²	20	20	20	17	16	20	20
Cylinders — Number	2	4	3	4	4	4	4
Cylinders — Diameter and stroke . mm.	(1) 575 × 720	450 × 720 660 × 720	530 × 760 570 × 650	440 × 660 620 × 690	440 × 650 650 × 650	450 × 650 680 × 700	440 × 650 640 × 650
Diameter of driving wheels. . m.	1.950	1.950	1.950	1.900	2.000	2.000	1.850
Grate area . . . . . m²	4.5	4.43	5.0 (3)	3.5	4.25	5.0	3.76
Heating surface — Firebox . . . . m²	18.7	26.20	25.19	20.3	15.68	27.5	20.68 (5)
Heating surface — Tubes . . . . . m²	205.0	197.00	243.16	194.5	190.57	220.5	191.00
Heating surface — Total . . . . . m²	223.7	223.20	268.35	214.8	206.25	228.0	215.90
Superheating surface . . . . m²	73.8	94.2	92.81	57.2	47.26 (4) 45.81 (1)	90.9	60.60
Total weight . . . . . t.	107	117.2	126.8	100.5	96.3	126.1	106.3
Adhesive weight . . . . . t.	60	74.6	80.8	56.8	55.5	78.8	75.5

(1) The 1402 locomotive has 540-mm. cylinders, but is fitted with a booster.
(2) The State Railways also have locomotives of this type.
(3) Fitted with mechanical stoker.
(4) According to the type of economiser.
(5) Surface of Nicholson siphon 4.216 m².

650-t. (640 Engl. tons) express trains on the level at speeds close to the authorised maximum of 120 km. (75 miles) an hour. The speed must not fall below 90 km. (56 miles) an hour on the long gradients of 1 in 200, the ruling gradients on the lines these trains run over.

The frame has been reinforced by using thicker and deeper frame plates, with the fewest lightening holes possible, cross braced by cast steel stays of large dimensions extending from the lp cylinders to the crank axle. Particular attention has been given to the lubrication. Large diameter lp piston valves have been fitted. The steam passages have been made as short as possible and of such shape as will minimise the resistance to the flow of the steam.

The Paris-Orleans Company's 4-8-0 engine converted from a *Pacific* engine with 1.85-m. (2 ft. 9 1/2 in.) wheels is working on the Paris-Toulouse line via Montauban. The engine was rebuilt to give additional adhesion so that trains of 700 t. (689 Engl. tons) could be worked over the 1 in 100 gradients instead of 500 t. (492 Engl. tons), the former maximum *Pacific* load.

The designs of the first of these engines were put in hand at the end of 1931. The engine went into traffic in 1932 and underwent many tests both in service and at constant speed with counter-pressure locomotives. This engine was designed on the same principles as the *Pacific* type mentioned above, with the special feature that, in

spite of its very great power, it had a narrow firebox the length of which had been increased to 3.80 m. (12 ft. 5 5/8 in.).

This engine showed it could work 800-ton (787 Engl. tons) trains up 1 in 200 gradients at 95 km. (59 miles) an hour; 575 t. (566 Engl. tons) up 1 in 166 gradients at 110 km. (68.3 miles) an hour; 530 t. (522 Engl. tons) up 1 in 100 gradients at 85 km. (52.8 miles) an hour.

The drawbar horse power developed is frequently 2 400 to 2 600 when accelerating on the gradients. The continuous indicated horse power has reached 3 500 and up certain gradients 3 700 to 3 800 with peaks of 4 000. In spite of the relatively small driving wheels and being an eight-coupled engine, this locomotive has run at 140 km. (87 miles) an hour, with a load of 575 t. (566 Engl. tons) over practically level stretches of track.

Medium-speed locomotives. — The State, Nord, Paris-Lyons-Mediterranean and the Paris-Orleans have put into service simple and compound *Mikado* (2-8-2) engines for working heavy goods trains. The Paris-Lyons-Mediterranean often uses these engines to haul the express or fast trains over its heavily graded lines. The Alsace-Lorraine Railways have introduced 4-8-4 tank engines for the same class of traffic.

The leading dimensions of these engines are as follows (table 5) :

TABLE 5. — **Leading dimensions of medium-speed locomotives.**

RAILWAY.	STATE.	NORD.	P.-L.-M.	P.-O.	A.-L.
TYPE.	2-8-2	2 8-2	2-8-2	2-8-2	4-8-4
CLASS.	141.001-141.250	4.1101-4.1150	1.4.1-C	5811-5960	T.20
System (simple or compound)	S E	C	C	S E	C
Type of superheater	Schmidt	Schmidt	Schmidt	Schmidt	Schmidt
Type of feed water heater	Worthington		(1)		ACFI
Boiler pressure kgr./cm²	12	16	16	12	16
Cylinders — Number	2	4	4	2	4
Cylinders — Diameter and stroke mm.	620×700	510×650 720×700	510×650 720×700	620×700	420×650 630×650
Diameter of driving wheels m.	1.650	1.650	1.650	1.600	1.660
Grate area m²	3.80	4.26	4.25	4.69	3.08
Heating surface — Firebox m²	15.10	15.41	15.68	14.32	15.7
Heating surface — Tubes m²	192.25	194.36	190.57	208.80	140.9
Heating surface — Total m²	207.35	209.77	206.25	223.12	156.6
Superheating surface m²	64.0	63.8	48.5	72.0	48.3
Total weight t.	86.9	95.0	96.3	92	121.7
Adhesive weight t.	65.0	70.7	70.9	69.5	67.4

(1) Some of the locomotives are fitted with Dabeg, ACFI, or Worthington feed water heaters.

Suburban engines. — Most of the railways have had to use eight-coupled engines with either bogies or bissel trucks at the outer ends for their suburban working.

Table 6 shows their leading dimensions on the various Systems.

TABLE 6. — **Leading dimensions of suburban engines.**

RAILWAY. TYPE. CLASS.	EST 2-8-2 141.701-141.742	STATE (1) 2-8-2 42.001-42.020	NORD 2-8-2 4.1200	P.-L.-M. 4-8-4 242 AT-BT	P.-L.-M. 4-8-4 242 CT-DT
System (simple or compound)	S E	S E	S E	C	C
Type of superheater	D M	Schmidt	Schmidt	Schmidt	Schmidt
Type of feed water heater			ACFI		
Boiler pressure kgr./cm²	16	12	18	16	16
Cylinders — Number	3	2	2	4	4
Cylinders — Diameter and stroke mm.	510 × 660	600 × 650	640 × 700	420 × 650 630 × 650	420 × 650 630 × 650
Diameter of driving wheels m.	1.420	1.540	1.550	1.650	1.500
Grate area m²	2.80	2.80	3.1	3.08	3.08
Heating surface — Firebox m²	17.30	15.50	18.00	16.13	16.20
Heating surface — Tubes m²	122.33	154.41	202.00	157.02	157.02
Heating surface — Total m²	139.63	169.91	220.00	173.15	173.22
Superheating surface m²	45.3	49.51	70.0	56.21	45.47
Total weight t.	107.3	96.2	122	120	117.3
Adhesive weight t.	75	72.3	80	65	64
Capacity of water tanks m³	13	8.5	10	12	12
Capacity of coal bunkers t.	4	4	5	5	5

(1) The State Railways also have a number of 2-8-2 locomotives of the Est type.

Fig. 3. — 2-8-2 class 141.700 tank engine, French Est Railway.

The 2-8-2 Est engines can haul trains of 500 tons at speeds of 95 km. (59 miles) an hour.

The Nord engine can give a sustained drawbar horse power of over 1 700 and maintain a speed of over 100 km. (62 miles) an hour up gradients of 1 in 200. With 10 % cut-off, 112 km. (70 miles) an hour has been maintained up gradients of 1 in 200 with 482-t. (474 Engl. tons) trains.

The Paris-Lyons-Mediterranean 4-8-4 engines are used for suburban working (Class 242 AT and BT) or for branch lines (242 CT and DT).

Goods locomotives. — As a rule ten-coupled engines of the leading dimensions given in table 7 are used for working heavy goods trains on the various Railways.

TABLE 7. — **Leading dimensions of goods locomotives.**

RAILWAY. TYPE. CLASS.	EST (1) 2-10-0 150.001-150.195	NORD 2-10-0 5-1200	P.-L.-M. 2-10-2 151 A	CEINTURI 2-10-2 5001-5012	A.-L. 2-10-0 G 12	ALL RAILWAYS. 2-8-0 Baldwin.
System (simple or compound) .	S E	C	C	S E	S E	S E
Type of superheater	D M	Schmidt	Schmidt	Schmidt	Schmidt	Schmidt
Type of feed water heater . .	(2)	ACFI	Dabeg	ACFI		
Boiler pressure . . kgr./cm²	14	18	20	14	14	13
Cylinders — Number	3	4	4	2	3	2
Cylinders — Diameter and stroke . mm.	560 × 660	490 × 640 680 × 700	480 × 650 745 × 700	600 × 650	570 × 660	533 × 711
Diameter of driving wheels m.	1.400	1.550	1 500	1 350	1.400	1.410
Grate area . . . . . m²	3.25	3.48	5	3.57	3 9	2.53
Heating surface — Firebox . . . m²	20.38	20.30	23.24	15.0	14.19	15.70
Heating surface — Tubes . . . . m²	182.98	175.68	220.53	183.0	180.77	142.46
Heating surface — Total . . . . m²	203.36	195.98	243.77	198.0	194.96	158.16
Superheating surface . . . m²	65.57	61 01	91.64	55.6	68.42	45.72
Total weight . . . . . t.	97	102	122.6	112.0	93.1	75.7
Adhesive weight . . . . t.	82	89	92.5	90.0	80	65.7

(1) The State Railways have a number of 2-10-0 engines of the Est type. — (2) The latest engines taken delivery of are fitted with Metcalfe exhaust steam injectors.

The Est 2-10-0 engines can haul :

Trains of 2 200 t. (2 165 Engl. tons) at 65 km. (40.4 miles) an hour on the level.
Trains of 1 600 t. (1 574 Engl. tons) at 40 km. (25 miles) an hour up 1 in 166 gradients.
Trains of 1 150 t. (1 131 Engl. tons) at 30 km. (18.6 miles) an hour up 1 in 100 gradients.

The P.-L.-M. *Santa Fe* engines have worked trains of 2 000 t. (1 968 Engl. tons) made up of bogie coal wagons at 55 km. (34.2 miles) an hour up 1 in 200 and 1 400 t. (1 378 Engl. tons) of ordinary stock up 1 in 100 at 45 km. (28 miles) an hour.

The particular novel feature of these engines is the cylinder arrangement, as all four are placed outside the frames.

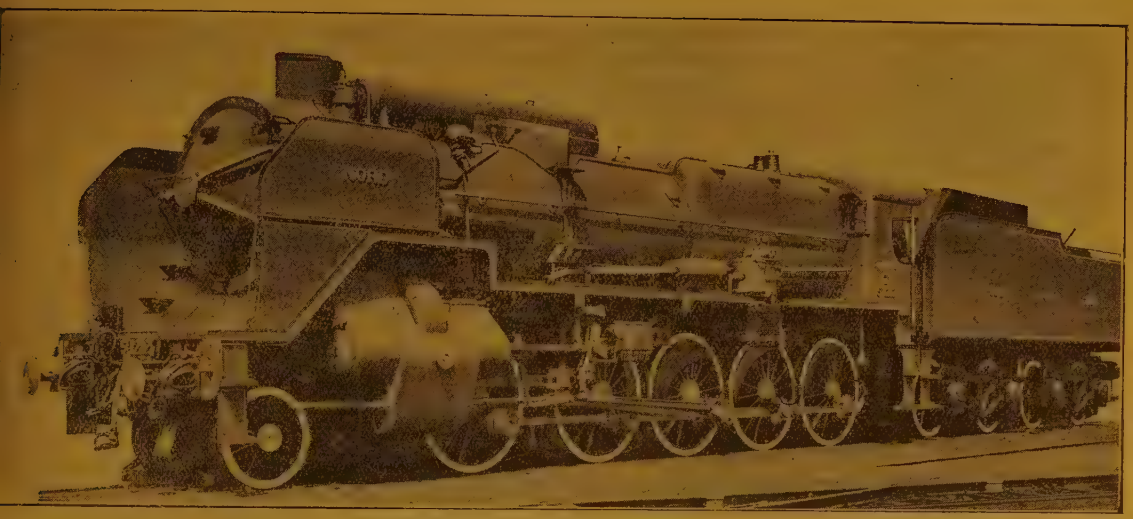


Fig. 4. — 2-10-0 class 5.1200 locomotive, Nord Railway.

Fig. 5. — Paris-Lyons-Mediterranean Railway 2-10-2 locomotive, designed by the O. C. E. M.

The hp cylinders are placed about half way along the engine and drive the sixth pair of coupled wheels. The lp cylinders are at the front end and drive the third pair of drivers. The hp and lp groups of driving wheels are coupled

together in turn by two inside coupling rods at 90° between the third and fourth pairs of drivers.

The Alsace-Lorraine Railways are using pre-war 2-10-0 engines and have now under consideration 2-10-2 engines of greater power.

Finally, since 1918, the French railways have had added to their stock 1900 2-8-0 American locomotives which are used on goods trains concurrently with the *Consolidation* engines most of the railways used before the war, and with the 0-8-0 (former G-8[1]) or 0-10-0 (former G-10) handed over by Germany after the armistice.

Shunting engines. — The increasing length and weight of the trains has made it necessary to use more powerful shunting engines. Some of the railways have built such engines and others have converted out-of-date line engines into shunting engines.

These engines are used frequently to haul heavy trains over short sections of line.

The leading dimensions of some of the shunting engines put into service in the course of the last years are are shown in table 8.

TABLE 8. — **Leading dimensions of shunting locomotives.**

RAILWAY. TYPE. CLASS.	NEW LOCOMOTIVES.			Obtained by conversion of old locomotives.	
	Est. 2-10-2 151.751-151.780	State. 0-8-0 40.001-40.143	Nord. 0-10-0 5600	A. L. 2-10-2 T-19	P. L. M. 0-8-0 4 DM
System (simple or compound)	SE	SE	SE	SE	SE
Type of superheater	DM				Schmidt
Boiler pressure kgr./cm²	14	12	14	12	10
Cylinders — Number	3	2	2	2	2
Cylinders — Diameter and stroke mm.	560 × 660	480 × 600	610 × 660	600 × 650	610 × 650
Diameter of driving wheels m.	1.350	1.300	1.350	1.350	1.300
Grate area m²	3.06	1.80	2.27	2.77	2.3
Heating surface — Firebox m²	19.39	8.20	11.70	15.06	10.39
Heating surface — Tubes m²	168.98	101.80	135.85	235.46	91.32
Heating surface — Total m²	188.37	110.00	147.55	250.52	101.71
Superheating surface m²	67.07	»	»	»	29.01
Total weight t.	122.6	63.7	91 7	96.4	74
Adhesive weight t.	92.2	63.7	76.5	78.7	74
Capacity of — water tanks m³	10.3	7	10.7		7.0
Capacity of — coal bunkers t.	5	3	4.5		4.0

This review of steam locomotives may be ended by pointing out that the methods and equipment used in carrying out engine trials have also been much improved. New dynamometer cars equipped with the latest instruments have been built.

Very good results have been obtained by a modification of Professor Czeczott's method for testing and, if need be, per-

fecting new types of engines. The chief progress in this field has been the recent construction at Vitry of a locomotive testing plant to the most advanced designs, for the French Railways as a whole.

We cannot pass over in silence even in so rapid a review of the main developments in French locomotive practice the tests of entirely new designs of locomotives the French railways have undertaken since the war (such as high-pressure and articulated *(Garratt)* engines).

Steam rail motor coaches.

Although, for a long time, French rail motor coach design has favoured the internal-combustion-engined units, it should be recorded that the Nord Company recently ordered a Sentinel Cammel steam engine coach.

Electric locomotives and rail motor coaches.

Before the war, the only electrified lines in France were : some of the Midi Company's lines (Perpignan to Villefranche-de-Conflent, Lourdes to Pierrefitte); some suburban lines : Paris to Juvisy, on the Paris-Orleans, and Paris-Invalides to Versailles R. G. on the State; and finally two mountain lines : St. Gervais to Vallorcine on the Paris-Lyons-Mediterranean, and Villefranche-de-Conflent to Bourg-Madame on the Midi.

Post-war financial conditions brought electrification to the fore, and the Government, in 1920, standardised the conditions on the basis of direct current at 1 500 volts, and 3 000 volts in exceptional cases, these conditions not being applicable to certain suburban lines.

Three of the main line companies, at the request of the Government, drew up a programme for electrifying nearly 9 000 km. (5 600 miles) of their lines.

On two of these, the Midi and the Paris-Orleans, with the greatest length of electrified lines, overhead equipment was adopted. On the third, the Paris-Lyons-Mediterranean with little electrification, the third-rail system was selected.

A fourth system, the State, it should be noted, electrified its suburban lines, this electrification being special to itself and limited in extent.

As the methods followed by the railways concerned differ, each of their practices will be dealt with separately below.

Speaking as a whole, in view of the first electrification in France being as recent as 1900, the development in the rolling stock for such lines has not been in the direction of alterations nor of improvements progressively applied to existing types. As the electrification was gradually extended the companies were satisfied to put into service new designs of increasing power and speed.

Midi Railway.

The electrified lines operated by the Midi have grown continuously since the war and are now 1 500 km. (932 miles), or 35 % of the system.

The Company has built seven hydro-electric power stations of 157 000 kVA installed capacity.

The power transmission lines built by the Company amount to 805 km. (500 miles) of 150 000-volt lines linking up six large 150 000-volt centers. A 60 000-volt system over 1 300 km. (808 miles) long distributes the energy to 60 substations where the high-tension current is transformed into 1 500-volt current.

The most recent Midi practice is to use mercury vapour transformers in the substations and also to make the latter automatic.

Locomotives. — The Midi Company, in 1922, put into service the first of its 1 000-H.P. 1 500-volt d.c. locomotives.

These locomotives intended for passenger service are of the B_0-B_0 type, i.e. with two driving bogies, each pair of bogie wheels being driven by a motor through two trains of gears. The motors, four per locomotive, are nose-supported and are fed directly with 1 500-volt current. The locomotives can develop 1 000 H.P. continuous, and 1 400 H.P. hourly rating.

Fig. 6. — B_0-B_0 class E-4600 locomotive, Midi Railway.

These locomotives develop this continuous power at 50 km. (31 miles) an hour, and maintain it up to 74 km. (46 miles) an hour by shunting the field windings. Their maximum speed is 90 km. (56 miles) an hour. Four notches are provided for shunting the field windings, the last corresponding to 65 %.

These locomotives, 50 of which are in service, are fitted with cam shaft control and with regenerative braking.

Forty other B_0-B_0 locomotives of the same power and characteristics have been built for working goods trains. They differ from those mentioned above by the ratio of the gearing which is 5.07 and by the electric brake, which is of the resistance type controlled by varying the field of the motors. The weight of these engines is 74.2 t. (73 Engl. tons) and their maximum speed 60 km. (37.3 miles) an hour.

The Midi Company in recent years has put into service a new series of 140 locomotives of the B_0-B_0 type, which are slightly different from the previous ones. The power is greater, 1 600 H.P. continuous, and 1 800 H.P. hourly rating. The control is electropneumatic, and the electric braking is of the resistance type controlled by varying the amount of resistance inserted in the circuit.

Fifty locomotives of this type are intended to work passenger trains. The gear ratio is 3.475 and the maximum

speed is 90 km. (56 miles) an hour. The other 90 locomotives are for goods train working. They differ from the others by the gear ratio : 4.875, and the maximum speed, which is 75 km. (46.6 miles) an hour.

The Midi is now receiving a new batch of B_0-B_0 engines, 50 goods and 17 passenger, of the same power and dimensions as the earlier ones. The electric braking is regenerative, however. The total weight per locomotive has been increased to 80 t. (78.7 Engl. tons).

When the Midi Company decided to extend its electrification to lines with easy gradients, run over by express trains, up to 120 km. (75 miles) an hour, it built 10 high-speed 2 C_0 2 type locomotives.

The interesting feature of these locomotives with electropneumatic control is the use of vertical motors built up in a single casing in which the two armatures revolve in opposite directions and drive through bevels a double toothed wheel mounted on the middle of a quill surrounding the corresponding axle.

Lastly the Company has introduced a new series of 2 D_0 2 type high-speed electric locomotives capable of hauling much greater loads than the 2 C_0 2, whilst running at the same or even higher average speeds.

These new locomotives have four horizontal motors, each made up of a double motor in a single casing.

Each armature shaft of a double motor carries a pinion which drives a wheel fastened to one of the flanges of the quill. The rotation of the quill is transmitted to the driving wheels by flexible links on the outside of the wheels.

The first of these locomotives left the shops at the end of 1932. Six of them are now in service.

During their trials these engines worked 500-t. (492 Engl. tons) trains at 146 km. (91 miles) an hour, and 820 t. (807 Engl. tons) can be hauled at 130 km. (80.8 miles) an hour.

The B_0-B_0 locomotives of the Midi Company incorporate a number of interesting features :

— each motor drives its axle through two gears (one on each side of the locomotive); the toothed wheels are fastened to the wheel centres by a dovetailed joint held in place only by locking plates.

— coupling of two bogies together by a system of rubbing blocks and springs which allow the bogies complete freedom of movement on curves whilst preventing any hunting on the straight usual on locomotives with two independent bogies.

— increasing the period of body oscillation and in consequence improving the steadiness of the floor by lowering and reversing the concavity of the centres. The body is steadied by spring equalisers on the Robert triangle principle which take the place of the fixed side blocks usually fitted.

The electrical equipment of the locomotives has also been improved considerably. In place of the cam shaft control used on the first batch, electropneumatic contactors have been used on the new locomotives.

In addition, the power of the traction motors has been increased although they take up no greater space.

The maintenance of the electric locomotives has been found to be cheaper than that of the steam locomotives.

The leading dimensions of the Midi electric locomotives are given in table 9.

TABLE 9.

	$2C_02$ 3101	$2D_02$ 4801	B_0-B_0 4001	B_0-B_0 4101	B_0-B_0 4501	B_0-B_0 4601	B_0-B_0 4201	B_0 B_0 4701
Diameter of driving wheels . . m.	1.750	1.750	1.400	1.400	1.400	1.400	1.400	1.400
Length over buffers . . . . m.	14.500	16.800	11.830	12.870	11 850	12.870	12.870	12.870
Total weight . . . . . t.	105.6	121.9	74.2	77.8	72	77.8	80	80
Adhesive weight . . . . . t.	57	75.9	74.2	77.8	72	77.8	80	80
Number of motors	3 (1)	4 (2)	4	4	4	4	4	4
Gear ratio	63/18	111/32	76/15	78/16	69/22	73/21	78/16	73/21
Power per motor — continuous rating H.P.	440	900	230	395	230	395	395	395
Power per motor — hourly rating . . H.P.	615	975	260	445	260	445	445	445

(1) Twin vertical motors. — (2) Twin horizontal motors.

Electric rail motor coaches. — The Midi Company owns the following electric rail motor coaches :

— 13 converted vehicles from the former single-phase lines. Their equipment consists of 4 d.c. motors of 340 H.P. continuous rating and 620 H.P. hourly rating; cam shaft control.

— 15 vehicles of the same power for speeds up to 85 km. (52.8 miles) an hour.

— 15 motor vans for hauling trains on branch lines. These vehicles, of 680 H.P. continuous, and 850 H.P. hourly rating, can run up to 70 km. (44 miles) an hour.

The leading dimensions of these rail motor coaches are as shown in table 10.

TABLE 10.

	RAIL MOTOR COACHES			Motor brake vans
	ZAB$_4$Etyf	ZCEyf	ZACEyf	ZEyfp
Diameter of driving wheels . . . m.	1.020	1.020	1.020	1.020
Length over buffers . . . . . m.	19.140	21.404	21.404	15.470
Total weight . . . . . t.	55.7	64.2	64	60
Adhesive weight . . . . . t.	55.7	64.2	64	60
Number of motors	4	4	4	4
Gear ratio	63/17	63/17	63/17	63/17
Power per motor — Continuous rating. . H.P.	85	85	85	170
Power per motor — Hourly rating . . . H.P.	155	155	135	210
Number of seats	44	48	48	

Paris-Orleans Company.

The Orleans Company has drawn up a very comprehensive scheme of electrification of its lines with heavy traffic, in consequence of the construction of the high-tension grid linking up the

steam power stations in the Paris area (Gennevilliers and Vitry) with the water power stations in the Central Plateau (Eguzon, Coindre, la Cellette, and Marèges).

The primary grid system of 220 000 volts feeds the secondary 90 000-volt system from which the substations take their supplies and convert the 50-cycle three-phase current into 1 500-volt d.c. current. The overhead wire supplies this current to the locomotives.

The first section of the programme, Paris-Vierzon and Brétigny-Dourdan, was completed some years ago and 19 % of the total traffic could then be worked electrically. This percentage has been increased considerably since the Orleans-Tours line was opened to electric operation in July, 1933. When the electrification of the lines between Vierzon and Brive is completed, that is to say towards the end of 1935, one third of the Company's traffic will be operated electrically.

Locomotives. — For long-distance train working, the Orleans Company began by ordering 200 type $B_0 + B_0$ locomotives developing 1 400 to 1 700 H.P. and weighing 70 to 77 t. (68.9 to 75.8 Engl. tons). Each locomotive has four nose-supported motors each driving an axle through gears. They can haul 1 200-t. (1 181 Engl. tons) goods trains at a maximum speed of 50 km. (31 miles) an hour, or passenger trains of 500 t. (492 Engl. tons) at a maximum speed of 90 km. (56 miles) an hour.

Ten of these locomotives have recently had the gear ratios altered so that they can be run faster than 90 km. an hour. As altered, they can handle 450 tons at a sustained speed of 105 km. (65.2 miles) an hour on the level.

When the speed has to exceed 105 km. with heavy trains, a much more powerful type of locomotive better suited for high speeds is required.

As the railways and builders had little experience of such locomotives when 1 500-volt d.c. electrification was started, the Orleans Company ordered for trial purposes five high-speed locomotives of different designs so as to find out, by long-period trials the most suitable type. These five locomotives belonged to the following three principal types :

— the 2 C_0-C_0 2 (gearless), of 3 000 H.P., with the armature keyed direct on the axles;

— the 2 D 2 with rod drive, of 4 400

Fig. 7. — 2 D_0 2 class E-503-527 locomotive, Paris-Orleans Railway.

H.P., with the four motors on the suspended frame, grouped in pairs, each pair driving two axles coupled by rods on the « Kando » system;

— the 2 D_0 2, with gear drive, of 3 600 H.P., each of the four motors on the suspended frame driving one axle through a flexible drive consisting of gears, rods, and toothed segments of the « Buchli » type.

This latter type having shown itself much the best, the Orleans Company ordered, for the Orleans-Tours electrification, 25 locomotives to this design.

It also ordered, for trial purposes, four 2 D 2 locomotives mechanically and electrically like the 25 above locomotives, but with a different method of transmission of the torque from the motor to the axles.

These locomotives now being delivered, are of 3 700 H.P., weigh 140 t. (138 t. Engl. tons) and can haul 800 t. (787 Engl. tons) on the level at a sustained speed of 120 km. (75 miles) an hour, and lighter trains up to 150 km. (93 miles) an hour.

750-t. (738 Engl. tons) trains can be hauled at 75 km. (46.6 miles) an hour up gradients of 1 in 100.

The leading dimensions of the Orleans Company's electric locomotives are given in table 11.

TABLE 11.

	2 D_0 2 503 to 527	$B_0 + B_0$ 1 to 80	$B_0 + B_0$ 101 to 188	$B_0 + B_0$ 201-204 221-224	$B_0 + B_0$ 205-220	$B_0 + B_0$ 225-240
Diameter of the driving wheels m.	1.750	1.190	1.300	1.300	1.300	1.300
Length over buffers . . m.	17.780	12.700	12.580	13.100	13.100	12.754
Total weight . . . . . t.	141	69.2	76.7	77.4	78.0	73.2
Adhesive weight . . . . t.	80	69.2	76.7	77.4	77.8	73.2
Number of motors	4	4	4	4	4	4
Gear ratio	2/31	65/21	73/21 or 67/25 (1)	69/22 74/17 (2)	69/20	69/22
Total power { continuous rating H. P.	3 300	1 320	1 500	1 240	1 320	1 240
Total power { hourling rating . H. P.	3 700	1 640	1 720	1 420	1 680	1 420

(1) 10 locomotives are fitted with these gears for working express trains.
(2) Locomotives 221 to 224.

NOTE. — The 201 to 240 locomotives are mainly used for shunting or for working short-distance trains.

Electric rail motor coaches. — When the main Paris-Vierzon section was electrified at 1 500-volt d.c. current, the old 600-volt suburban stock was replaced by 80 BB type 1 500-volt rail motor coaches. These motor units can be used with two trailers to form reversible train sets, which can be formed in groups of two or three to provide trains the power/weight ratio of which remains constant.

The leading dimensions of these rail motor coaches are the following :

	ZC⁹Eyp
Diameter of drivers . . . . . m.	1.050
Length over buffers . . . . . m.	21.100
Total weight . . . . . t.	65.15
Adhesive weight . . . . . t.	65.15
Number of motors	4
Horse { continuous rating.	760
power { hourly rating	990
Number of seats	92

Paris-Lyons-Mediterranean Company.

The Saint-Gervais to Vallorcine mountain line, electrified prior to the war, still retains its special features, so we need not deal with it in this review of main line electrification.

The Paris-Lyons-Mediterranean Company, in 1929 and 1930, substituted electric for steam traction on the Chambéry-Modane section of the Paris-Turin international line which has very difficult gradients.

The 42 000-volt 50-cycle three-phase current is supplied to the substations by a central station fed by a group of hydro-electric power stations of the region.

The locomotive stock includes high-speed machines such as the 2-6-2 AE, and medium-speed engines.

The 2-6-2 AE locomotive is of the 2 C_0-C_0 2 type and is the most powerful electric locomotive with a single body in use at the present time. During its tests it hauled between Chambéry and Saint-Jean-de-Maurienne trains of 800 t. (787 Engl. tons) without the speed dropping below 90 km. (56 miles) an hour, except on some kilometres of 1 in 66, where it fell to 85 km. (52.8 miles) an hour. (It should be noted that the last shunt position was not used).

The power of the medium-speed locomotives is about 2 300 H.P. They can work 900-t. (886 Engl. tons) trains over gradients of 1 in 66. They are fitted with regenerative braking.

The leading dimensions of the Paris-Lyons-Mediterranean electric locomotives are as follows (table 12).

TABLE 12.

	High-speed locomotives.				Medium-speed locomotives.		
	2 B_0—B_0 2 242-AE.	2 B_0—B_0 2 242-BE.	2 C_0—C_0 2 262-AE.	1 A_0-D_0 + B_0-A_0 1 161-AE.	1 C_0+C_0 1 161-BE.	1 C_0+C_0 1 161-CE.	1 C_0+$C_0$1 161-DE.
Diameter of driving wheels . m.	1.590	1.590	1.590	1.240	1.240	1.390	1.430
Length over buffers . . . m.	21.000	20.000	23.800	20.580	20.580	21.200	21.600
Total weight . . . . . t.	130.1	124.6	159	118.9	122	125	129.5
Adhesive weight . . . . . t.	71.5	73.6	107.4	80.48	98.9	102	111.4
Number of motors	8	8	12	6	6	6	6
Gear ratio	93/24	82/21	86/27	61/25	68/18	76/17	87/21
Total power { continuous rating . H.P.	1 800	2 200	3 900	1 800	1 900	1 700	1 800
Total power { hourly rating . . H.P.	2 300	2 500	4 900	2 220	2 200	2 100	2.100

State Railways.

The State Railways, as we have already said, have only electrified their suburban services. The electrification is therefore too restricted and special to be dealt with at any length here.

The lines served, however, amount to 100 km. (62 miles) in length and the electrification is by third-rail at 650 volts d.c.

The leading dimensions of the rail motor coaches and locomotives actually in use are as shown in table 13.

TABLE 13.

	Locomotives.	Rail motor coaches.		
		2nd series.	3rd series.	4th series.
Diameter of driving wheels . . . m.	1.200	0.925	1.100	1.100
Length over buffers . . . . . m.	12.140	22.840	19.920	19.920
Total weight . . . . . t.	60	74	57	57
Adhesive weight . . . . . t.	60	49	57	57
Number of motors	4	4	4	4
Gear ratio	67/21	65/27	71/21	71/21
Power per motor: continuous rating . . H.P.	140	50	50	50
Power per motor: hourly rating . . . H.P.	275	165	165	165
Number of seats		40	58	90

Internal-combustion-engined rolling stock.

The use of internal combustion engines for railway purposes is relatively recent. The improvement in explosion motors and especially the advance made in the diesel engine has made their use for traction purposes of first importance.

Locomotives and locotractors.

The internal combustion engine which, unlike the steam boiler, only consumes fuel when working, should first of all be used on shunting work, which is so often interrupted.

In consequence, since the war, in some stations petrol-engined locotractors have been put into service at a

Fig. 8. — 800-H.P. diesel-electric locomotive, Ceinture Railway.

quick rate. The diesel engine followed. Subsequently locomotives with diesel engines have been considered and even used, as on the Ceinture and on the Paris-Lyons-Mediterranean, for certain goods workings or for shunting.

Diesel-electric locomotives are under design and trial for working on the main lines. Some of the types tried, such as those tested on the Paris-Lyons-Mediterranean, for example, seem likely to have a real future.

The principal types of such locomotives in service are given in table 14.

TABLE 14.

TYPE. SERVICE.	Paris-Lyons-Mediterranean.					Ceinture.
	232 ADE (1) $2C_0 2$ Passenger.	4 ADE (1) $B_0 + B_0$ Passenger.	4 AMD $A_0 1 A_0 + A_0 1 A_0$ Shunting.	4 BMD $1 B_0 + B_0 1$ Shunting.	141 AMD $1 D_0 1$ Shunting.	$1 D_0 1$ Goods.
Diesel engine — Type	M A.N.	Sulzer	M.A.N.	Sulzer	M.A.N.	Sulzer
Diesel engine — Power in H.P. and r. p. m.	920 to 700 r.p.m.	750 to 630 r.p.m.	600 to 700 r.p.m.	600 to 670 r.p.m.	600 to 700 r.p.m.	800 to 700 r.p.m.
Diesel engine — Number of cylinders.	8	8	6	8	6	8
Diesel engine — Cylinder diameter. mm.	280 × 380	310 × 370	280 × 380	280 × 340	280 × 380	
Number of traction motors . .	3	4	4	4	4	4
Diameter of driving wheels m.	1.250	...	1.150	1.210	1.250	1.150
Length over buffers . . . m.	15.130	14.000	12.900	13.500	14.000	14.300
Total weight . . . . . t.	95	73.2	84.3	83.8	92.9	88.5
Adhesive weight . . . . . t.	51	73.2	70 8	71.3	71.7	66.5

(1) For the Paris-Lyons-Mediterranean Algerian lines, and under test on the Paris-Lyons-Mediterranean in France.

Rail motor coaches.

The greatest development, and one which is steadily increasing, in the use of the internal combustion engine, has been in passenger service.

Owing to the economic crisis and road motor competition the railways have had to find an economical method of working their branch lines, which would also be flexible and meet the wishes of the public.

The rail motor coach appears to be the best solution of this problem and the railways have started, on a large scale, to carry out the vast programme they have drawn up.

172 units with internal combustion engines had been ordered, by the 1st September, 1933, 37 with diesel and 35 with petrol engines. Since that date very satisfactory results have been obtained commercially on the lines on which these units have been in service.

The railways intend — and the new order for 260 units confirms it — to extend this experiment considerably in 1934 by setting up new radiating services about certain suitably selected centres on their secondary lines and by introducing high-speed services on their main lines.

This latter method of using rail motor coaches was introduced on the State Railways in 1933, between Paris and Trouville, by a two-hour service during the summer season.

The Paris-Lyons-Mediterranean proposes to establish fast services between Paris and Nice, and has ordered the necessary rolling stock : three Bugatti motor coaches and three trailers. The set consisting of one motor coach and one trailer provides 75 very comfortable seats on the lines of the Pullman coaches, with a bar and buffet for serving cold meals. These units can run at 130 km. (80.8 miles) an hour over the long gradients of 1 in 125 on the Paris-Nice line.

The French Nord is putting into service two Diesel-electric sets of 800 H.P. for express working between Paris and Lille. These sets consist of either two motor units each of 400 H.P. or two motor units with a vehicle sandwiched between them. They have to cover the 250 km. (155.3 miles) in 2 h. 15 m., with a maximum speed of 140 km. (87 miles) an hour, and two stops (Arras and Douai).

The leading dimensions, so far as they are known, of the internal-combustion-engined rail motor coaches ordered by the railways are as given in table 15.

Carriages.

As far back as 1920, chiefly for greater safety, the French railways have been replacing their wooden-bodied stock by all metal vehicles. The work achieved is shown by the following figures :

	Number of metal coaches.	
	In service.	Under construction.
Main line . . .	2 562 (1)	178
Suburban . . .	1 447 (2)	181
Total . .	4 009	359

Main line stock.

The main features of these vehicles is that the body as well as the frame plays its part in giving the needed strength. The frame is no longer merely the support of the body but forms part of it. This idea has been carried out in various ways.

O. C. E. M. design. — The main object the O. C. E. M. (Central Rolling Stock Designing Office) had in mind was to design vehicles not appreciably heavier than modern wooden-bodied stock, i. e. 40 to 43 tons. It had been requested to see that the new design did not involve special tool equipment, and that it cost about the same as the old stock.

To meet these requirements, the O. C. E. M. was led to use rolled sections or bent plates for the body framing, and to use the same end as far as the body bolster on all classes of stock.

As the underframe should be strong enough to withstand buffing shocks along the buffer line, the O. C. E. M. designed its vehicles so that, through a transverse section, the weight of the metal decreases from the frame to the sides and from the sides to the roof.

The frame is built up of rolled sections with one-piece sole bars with a set at the cast steel body bolster. The cant rail consists of two large-section angles running right through and forms the top member of the girder of which the sole forms the lower. The rolled Z bar pillars divide up the body side. The angle roof sticks form the arch for the roof and also cross brace the two sides. This gives a prismatic system with four reinforced edges solidly cross stayed. The corrugated sheet floor finished in Terrazolith helps to square up the frame to which it is riveted.

The ends are strongly reinforced by steel pressings and form the anti-shock device.

Finally, to save money on tools, patterns, drawings, marking off, etc., the O. C. E. M. has standardised certain dimensions for the width of compartments, corridors, etc...

(1) 469 converted on the P. L. M.

(2) Including electric railcars of the State, P. O. and Midi Railways.

TABLE 15.

BUILDERS.	Number of railcars ordered.	ENGINES. Type.	Number.	Horse power and r. p. m.	Transmission.	Speed.	Wheel arrangement.	Length of the vehicle.	Tare.	Number of seats.	Area of luggage compartment.	REMARKS.
				H.P. R.p.m.		km./h.		m.	t		m²	
Renault	1 A. L.	Renault diesel	1	200 at 1400	Mech.	90/100	B-2	17.400	22	59	3	
	8 A. L.	Do.	1	220 » 1500	Mech.	90/100	B-2	13.000	25	70	4.75	
	10 (6 Est, 4 State)	Do.	1	200 » 1400	Mech.	90/120	B-2	17.400	22	56	7	1 with rustless steel body. — Tare 19 tons.
	1 State	Renault petrol	1	90 » 1900	Mech.	85	A-A	11.730	16	39	3.75	
	10 State	Renault diesel	1	80 » 1500	Mech.	80	1-A	9.133	11	34		2 rail motor coaches with one 70-H.P. engine only.
	4 State	Do.	1	85 » 1500	Mech.	90	1-A	9.133	11	34	3.50	
	2 P.L.M.	Renault petrol	1	110 » 2200	Mech.	65	B-2	16.510	22	57	6	Old rail motor coach with heavy railway type frame.
	2 P.L.M.	Renault diesel	1	200 » 1400	Mech.	100	B-2	17.400	25	56	4	
	2 P.O.	Do.	1	200 » 1500	Mech.	90/120	B-2	17.400	25	56	2.40	
	4 P.O.	Do.	1	220 » 1500	Mech.	90/120	B-2	18.720	25	53	7.6	
	38 State	Do.	1	220 » 1500	Mech.	110	B-2	18.950	21	42	10.0	
Michelin	10 (Est 2, State 2, Nord 4, P.O. 2)	Panhard petrol	1	96 » 2200	Mech.	90	B-1-2	12.660	4.8	24	6	
	24 (Est 2, State 20, Nord 2)	Hispano petrol	1	140 » 2200	Mech.	95	C-3	13.600	6.5	36		
	2 State		1	220 » 3000	Mech.	105	C-3	13.793	6.5	32		
Entreprises Industrielles charentaises	17 (1 A. L., 4 State, 8 Midi, 4 P.L.M.)	Peugeot-Junkers diesel	1	80 » 1500	Mech.	90	1 B 1	14.800	9.5	60	5	
	2 Est	M.A.N. diesel	1	120 » 1400	Mech.	97/100	B 2	18.000	15	60	10	
	1 Midi	Peugeot-Junkers diesel	1	80 » 1500	Mech.	90	1-A	12.000	6.5	51	5	
	4 Midi	Do	1	105 » 1500	Mech.	90	1-A	12.000	8	40	6	
	4 State	Saurer diesel	2	140 » 1500	Mech.	125	B-2	23.007	22	82	10	

TABLE 15 (*continued*).

BUILDERS.	Number of railcars ordered.	ENGINES. Type.	Number.	Horse power and r. p. m.	Transmission.	Speed.	Wheel arrangement.	Length of the vehicle.	Tare.	Number of seats.	Area of luggage compartment.	REMARKS.
				H.P. R.p.m.		km./h.		m.	t.		m²	
de Dietrich	34 (4 P. O., 14 A. L., 8 Est., 6 State.)	Peugeot Junkers diesel	2	105 at 1500	Mech.	100	1-A 1-A	18.120	23	75	4.50	
Schneider	1 State	S. O. M. U. A. petrol	1	64 » 1200	Mech.	60	A-1	8.530	14	20	4.25	Old vehicles rebuilt (being converted into motor brake vans).
	10 State	Do.	1	85 » 1300	Mech.	73	A-1	8.530	14.5	20	6.25	
Baudet Donon Roussel	2 Est	C. O. D. R. A. diesel	1	150 » 1800	Mech.	95/100	A-1	14.450	11	40	5	Twin rail motor coaches.
	2 Nord	Do.	2	110 » 1500	Mech.	100	B-B	19.200	26	65	10	
	4 P. L. M.	Peugeot-Junkers diesel	1	100 » 1500	Mech.	95	A-1	10.840	16	40	4	Twin rail motor coaches.
	2 P. O.	Do.	1	110 » 1500	Mech.	90	A-1	10.840	11	34		
Aciéries du Nord (1)	2 State	M.A.N. diesel	1	210 » 1500	Mech.	105	B-2	22.200	30	74	6	For the Paris-Orleans rail motor coaches, tare 31 = t.
	4 (2 P.L.M., 2 P.O.)	Do.	1	170 » 900	Mech.	90	B-2	20.917	33.7	62	9	
	2 Nord	Do.	1	250 » 1200	Electr.	100	2-B_0	21.371	30	66	9	
	4 P. O.	Do.	1	280 » 1400	Mech.	120	B-2	23.300	33	64	10.0	
Cie Générale de Construction	4 State	Do.	1	105 » 1400	Mech.	90	AA	12.800	13.5	44	3.80	
	4 P. L. M.	Do.	4	140 » 1400	Mech.	90	A-1	12.800	17.7	44	2.50	
Bugatti	4 State	Bugatti petrol	4	200 » 2000	Mech.	130	1B1+1B1	23.160	23	52		
	5 State	Do.	2	200 » 2000	Mech.	150	2-B-B-2		12	72		
	3 P. L. M.	Do.	1	200 » 2000	Mech.	130	1B1+1B1	(2)		79		
S. O. M. U. A.	2 P. L. M.	Peugeot-Junkers diesel	1	80 » 1500	Mech.	90	1-A	11.355	11.3	40	4	Coupled with a trailer with a single pair of wheels.
	2 State	M.A.N. diesel	1	140 » 1400	Mech.	76	A-A-1	21.940	19	76	6.80	
Franco-Belge	4 Nord	Maybach diesel	1	410 » 1400	Electr.	140	2-B_0	20.620	45	44	6	2 trailers in addition.
Compagnie Française de Matériel de Chemin de fer (Le Tilleul)	2 Nord	Saurer diesel	2	130 » 1500	Electr.	105	1-AA-1	18.600	30	62	8.50	
	1 P. L. M.	Do.	1	130 » 1500	Mech.	90	1-A	12.290	18	43	4.50	
	1 P. L. M.	Do.	1	130 » 1500	Electr.	90	1-A	12.290	19	43	4.50	
Decauville	2 Nord	Do.	2	130 » 1500	Mech.	100	BB	21.000	26	64	9	
Berliet	2 P. L. M.	Berliet diesel	2	125 » 1500	Electr.	100	2-B		30	56	10	
Delaunay-Belleville	2 P. L. M.	Delaunay-Belleville diesel	1	85 » 1000	Mech.	90	A-A	11.960	11.2	40	4.40	
Batignolles-Bacalan	2 Est	C. O. D. R. A. diesel	2	150 » 1800	Mech.	95/100	A-1-1-A	20.000	28	60	10	
Fouga	1 Midi	Maybach diesel	1	280 » 1400	Mech.	120	4-1-B-1	16.500	14	50	6	

(1) The Paris-Lyons-Mediterranean railcars have a Renk gear box with jack shaft and rod drive.
The Paris-Orleans railcars have a S. L. M. Winterthur gear box with gear transmission.
(2) Coupled to trailers. Length of the set = 43.5 m.

The results obtained by such standardisation have been remarkable. In all the vehicles in question, the following parts are *identical :* all steel castings, all steel pressings; all forgings; all hand and air brake riggings, electric light fittings, heating (except the radiators which have an extra tube in the first class); all metal doors; all lavatory equipment, except the wash basins and fittings; almost all brass work which is nickel plated in the 1st and 2nd class but simply polished in the 3rd, nearly all wood mouldings. The sections and plate thicknesses are all exactly the same in all classes.

Out of the 1 022 patterns of attendant parts in a 3rd-class coach, 899 are the same as in the 1st. The 123 others include 72 fittings (seats, backs, wash basins, and accessories); 13 notice plates; 20 parts of the same section but of different length (brake levers, window frame cross bars, etc...); and 25 small details.

TABLE 16. — **Leading dimensions of the main-line vehicles of O. C. E. M. design.**

TYPE.		A^8yfi	$A3^1/_2B^5yfi$	A^3B^5yfi	B^9yfi	B^4C^5yfi	$C^{10}yfi$	C^8Dyi
Bogie wheel base . . . . . m.		2.500	2.500	2.500	2.500	2.500	2.500	2.500
Distance between bogie centres. m.		15.343	15.610	16.093	15.244	14.194	15.045	15.610
Length of the body . . . . m.		21.933	22.200	20.683	21.834	20.788	21.635	22.200
Width of the body . . . . . m.		2.938	2.938	2.938	2.938	2.938	2.938	2.938
Length over buffers . . . . m.		23.263	23.530	22.013	23.164	22.114	22.965	23.530
Number of seats.	1st class . .	48	21	18				
	2nd class . .		40	40	72	32		
	3rd class . .					40	80	40
	total	48	61	58	72	72	80	40
Length of the compartments.	1st class . m.	2.150	2.150	2.150				
	2nd class . m.	1.900	1.900	1.900	1.900	1.900		
	3rd class . m.					1.690	1.690	1.690
Tare weight . . . . . t.		47.0	50.7(1)	44.5	47.0	44.5	45.5	42.5

(1) With electric heating in addition to steam heating.

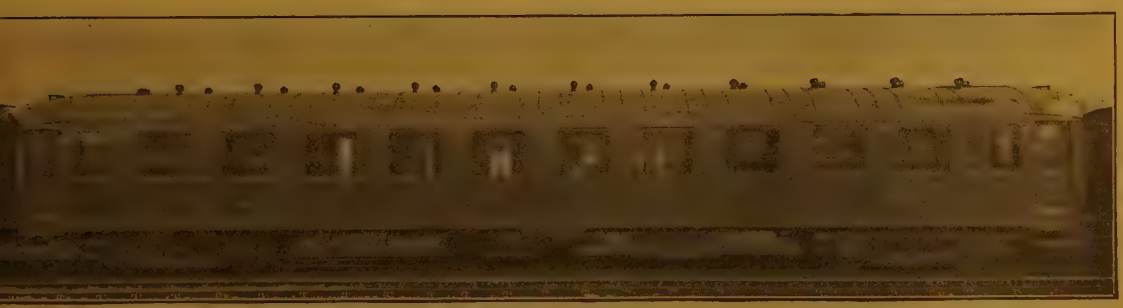


Fig. 9. — $C^{10}yfi$ main-line coach, designed by the O.C.E.M.

Fig. 10. — A^{s}yfi coach for fast express trains, Nord Railway type.

Fig. 11. — C^{10}yfi coach with side doors for express trains, Nord Railway type.

Dyle et Bacalan design. — Like the O. C. E. M. coaches, the design includes a body framing but greater use is made of steel pressings.

In this alternative design, the frame is triangulated by steel pressings in the form of St. Andrew's crosses, the floor not forming part of the frame as on the O. C. E. M. stock.

The side pillars are carried on the top flange of the sole bars and not on the side of the web. Angles are used to secure the pillars to the sole bars.

Nord design. — The Nord Company aimed at making the body as strong as possible to stand up to the shocks received in service and in case of collision, and obtaining perfect cross bracing, greatest steadiness at the highest speeds, and finally least air resistance.

The result of this investigation was the vehicle turned out in 1933, the very characteristic vehicle of the Nord. The coach is really a smooth tube in one piece and is built up of steel stiffened by steel rings or with cross partitions

between the compartments. This type of vehicle is formed of 3 to 4-mm. (1/8 to 5/32-inch) steel panels, cut out and pressed as required by the construction. The turned-in edges of these plates, electrically welded, stiffen this tubular shell and are used to join the sides with the rings and cross partitions.

The steel plate forming the tube is of the same thickness throughout. The frame built up of steel pressings carries at the ends two strong steel castings fastened to the tubular body to take the buffing and drawbar stresses. This type of vehicle is especially suitable for fast express train stock as it has no side doors and the outside surface is completely free from rivets, window frames, and joints. In stock for semi-fast trains side doors have, however, been used.

TABLE 17. — **Leading dimensions of main-line coaches on the Nord Railway.**

TYPE.		A^8yfi	A^3B^5yfi	A^3B^3Ddyi	B^9yfi	B^4D_3fi	$C^{11}yfi$
Bogie wheel base . . . . . m.		2.500	2.500	2.500	2.500	2.500	2.500
Distance between bogie centres m.		15.500	15.500	15.500	15.502	15.500	14.000
Length of body . . . . . m.		21.000	21.000	21.050	21.002	21.000	19.500
Width of body . . . . . m.		2.384	2.384	2.384	2.384	2.384	2.384
Total length over buffers . . m.		22.350	22 350	22.400	22.352	22.350	20.850
Number of seats.	1st class . .	48	18	18			
	2nd class . .		38	22	68	38	
	3rd class . .						88
	total	48	56	40	68	38	88
Length of compartments.	1st class . m.	2.150	2.152	2.152			
	2nd class . m.		1.910	1.910	1.910	1.908	
	3rd class . m.						1.610
Tare weight . . . . . t.		46.5	47	45.5	46.5	45.5	45.5

Est design. — The feature of the Est design is the reduction in tare weight obtained by using the steel scientifically, by simplifying the construction, and by the care given to make repairs and maintenance easy.

The Est coach is a tubular girder : « girder » to take the vertical loads, « tube » to resist the longitudinal and, if need be, lateral stresses.

The two sides form the web of the girder, the two flanges being the roof and the steel plate floor.

The part which can still be called the frame and which consists of a floor strengthened along its edges by two sole bars, have been built completely into the side and seat plates which have been extended downwards and turned up square for this purpose.

With this design, no body framing is needed. All that is necessary is to stiffen the plates with U shaped pressings.

The ends (vertical seat backs) built of strong pressed steel frames, are carried by drag boxes and pillars of pressed steel, the whole forming a shock absorbing device against telescoping in case of collision.

To simplify the design, construction, and maintenance, all coaches of the same class have the same frame, the only parts which vary being those affected by the size of the compartments and by the fittings and interior decoration. Erection has been simplified by welding.

It should be noted that the Est has not thought it necessary to give up using wood for the floors and interior linings, as it is light and comfortable besides insulating the coaches against cold and heat, and noise.

TABLE 18. — **Leading dimensions of main-line carriages on the Est Railway.**

TYPE.		$A^8yfi.$	$A^{3\,1}/_2B^5yfi.$	A^4B^1 EZyfi.	$B^9yfi.$	$B^1Dyfi.$	$C^{11}yfi.$	$C^5Dyi.$
Bogie wheel base	m.	2.500	2.500	2.500	2.500	2.500	2.500	2.500
Distance between bogie centres	m.	15.500	15.500	15.500	15.500	14.000	15.500	15.500
Length of body	m.	22.204	22.200	22.200	22.204	19.780	22.204	22.200
Width of body	m.	2.940	2.940	2.940	2.940	2.940	2.940	2.940
Total length over buffers	m.	23.530	23.530	23.530	23.530	21.110	23.530	23.530
Number of seats. 1st class		48	21	18				
Number of seats. 2nd class			40	32	72	32		
Number of seats. 3rd class							88	40
Number of seats. total		48	61	50	72		88	40
Length of the compartments. 1st class	m.	2.175	2.150—1.490	2.150				
Length of the compartments. 2nd class	m.		1.910	1.910	1.940	1.910		
Length of the compartments. 3rd class	m.						1.610	1.610
Tare weight	t.	48	49	47	47	41	48.5	43.5

Paris-Lyons-Mediterranean type. — The Paris-Lyons-Mediterranean possessed a very large stock of bogie vehicles with wood bodies.

It has progressively rebuilt the stock used on the express trains so as to give the passengers the same safety and comfort as in all-metal coaches.

The wood framing has therefore been replaced by a strong metal framing with U or L pillars riveted to the webs of the sole bars, which web consists of a 6-mm. (1/4 inch) thick plate continued up to the waist. The top of the pillars is fastened to a very rigid metal frame built up of two rivetted angles onto which are also fastened the U's and L's forming the roof sticks.

The roof itself is metal and so are the inside ceilings. The metal floor is the same as the O. C. E. M. design. The ends of the body are protected by a thick steel pressed plate assembled on pressed steel pillars, the whole being strongly tied into the rest of the body framing.

A number of P.-L.-M. metal coaches have been built to this design.

Other features of modern French main-line stock. — The modern main-line stock generally speaking is fitted with Pennsylvania type bogies, well known for their good riding qualities.

These bogies are either one-piece steel castings or are built up of steel castings.

All vehicles are electrically lighted by dynamo and battery; the lights can be turned low for the night. The Nord also uses lighting by turbo-generator fitted on the locomotive.

Steam heating is almost always fitted with compartment control. It has been improved considerably as, for example, by the use on many railways of new steam heating couplings with straight through passages.

Electric heating is being introduced on the electrified lines and on stock in international service.

The interior fitting out and decoration

Fig. 12. — C[11]yfi main-line coach, Est type.

Fig. 13. — Suburban coach, Est Railway type.

of the coaches has received much attention but the designs adopted differ on each railway.

Safety glass is being used more and more.

The vehicles have been made more comfortable. The 3rd-class seats have been upholstered and some railways are fitting seats with spring fillings.

Sleeping accommodation is becoming more widely used, and third-class berths have been introduced on some railways.

Luxurious sleeping compartments for two passengers, and in some case for one, have been built and fitted with every possible convenience. Special saloon sleeping compartments have also been provided for the use of wealthy travellers.

Suburban stock.

The suburban stock has been radically altered in recent years. Large-capacity all-metal vehicles built on similar lines to the main line stock with ample plat-

form space to facilitate the movement of passengers at stations have been provided. The O.C.E.M., Nord, and Est designs have been adapted for this class of stock.

Reversible rakes are becoming more and more general. The locomotive remains at either the head or rear of the train, in whatever direction the train runs. Special equipment — electric on the Nord and Paris-Lyons-Mediterranean, and pneumatic on the State — is fitted, by which the driver controls the regulator and reversing gear levers from the opposite end of the rake. Some of these rakes are fitted with central automatic couplings.

TABLE 19. — **Leading dimensions of the suburban stock.**

	Bogie wheel base.	Distance between bogie centres.	Length of body.	Length over buffers.	Length over coupler faces.	Number of seats.				Tare weight.
						1st cl.	2nd cl.	3rd cl.	Total.	
	m	m	m	m	m					t.
O. C. E. M. design :										
A^2yfp	2.500	13.684	19.884	21.214		88			88	38
A^2B^2yfp	2.500	13.684	19.884	21.214		21	63		84	38
B^3yfp	2.500	13.684	19.884	21.214			98		98	38
B^2Eyfp	2.500	13.684	19.884	21 214			81		81	37
C^3yfp	2.500	13.684	19.884	21.214				98	98	38
C^2Eyfp	2.500	13.684	19.884	21.214				81	81	37
NORD design :										
Ayi	2.500	14.500	20.000		20.850	64			64	45
AByi	2.500	14.500	20.000		20.850	24	58		82	44.5
BDyi	2.500	14.500	20.000		20.850		79		79	43.5
Cyi	2.500	14.500	20.000		20.850			98	98	43
CDsyi	2.500	14.500	20.000		20.850			79	79	44
EST design :										
Axxy	2.500	14.500	22.570	21.240		66			66	41.5
Bxxy	2.500	14.500	22.570	21.240			92		92	41.5
Cxxy	2.500	14.500	22.570	21.240				78	78	43
CDxxy	2.500	14.500	22.570	21.240				49	49	42.5

The most recent innovation in suburban stock has been the double-decker large-capacity coaches introduced by the State Railways on the Argenteuil and Conflans line. Large use has been made of light alloys and special nickel steels. Roller bearing axle boxes have also been fitted to reduce the starting and running resistances. The State Railways are building 40 new coaches of this type besides the 10 now in service.

Post Office stock.

At the end of the war, the Post Office only had at its disposal worn out wood-

Fig. 14. — 20.28-m. (66 1/2 ft.) Post Office van, designed by the O. C. E. M.

body stock consisting of bogie travelling post offices, some bogie with 18-m. (59 ft. 5/8 in.) bodies, others 4 and 6-wheeled, with 14-m. (45 ft. 11 in.) long bodies, and 4 and 6-wheeled auxiliary vans 11 and 14 m. (36 ft. 1 in. and 45 ft. 11 in.) long used as brakes for carrying sealed postal sacks.

In 1922, the O.C.E.M. was instructed to prepare new designs. The present Post

TABLE 20.

TYPE.	Length of the body.	Length over buffers.	Bogie wheel base.	Distance between bogie centres.	Tare.	REMARKS.
	m.	m.	m.	m.	t.	
PAyi.	20.280	21.570	2.500	14.680	40.5 to 43	Includes 1 sorting compartment between two gangways.
PAy	20.280	21.570	2.500	14.680	40	For the Alsace-Lorraine Railways; also has 1 compartment for sorting post parcels.
PAyi.	15.250	16.580	2.500	9.650	38	
PAtyf	15.250	16.580	2.500	9.650		These vehicles now under construction are for the Alsace-Lorraine Railways. They are arranged like the PAy.
PAtf.	10.700	11.830	7.400 (1)			
PEyi.	17.000	18.290	2.500	11.400	34	
PEActyf	17.000	18.330	2.500	11.400	36	Specially set aside for the Indian Mail.
PEyi.	17.000	18.330	2.500	11.400	36.5	

(1) 4-wheeled vehicle for secondary lines.

Office rolling stock consists of 574 all-metal vehicles.

They are built on the same lines as the O.C.E.M. all-metal bogie vehicles for the main lines. There are two types, however, the 1923 and 1930 designs. The main difference between these types lies in the way certain parts of the body framing are assembled. The openings in the body sides are reduced to the minimum in all these vehicles and the lighting by day is through deck lights.

The leading dimensions of this stock are as shown in table 20.

Brake vans.

The French railways were led to resort also to all-metal construction for the brake vans, which were designed by the O.C.E.M. for both express and ordinary trains.

As regards the vans for express trains, the O.C.E.M. designed two types, one with a raised guard's look-out, and the other with a periscope. The periscope for sighting the signals, first used by the Nord, simplifies the construction as no look-out is needed; it reduces the weight and is cheaper. The guard remains on the floor and can watch the line either seated or standing.

In the case of vans for slow trains, the O.C.E.M. designed a standard vehicle of great strength with either a look-out or a periscope.

At the present time, the railways have in service nearly 1 800 express and slow train vans, 1 300 of which are of the standard design.

The leading dimensions of this stock are as follows :

	Express brake vans.				Ordinary brake vans.
	DPyi	Dq (3)	Dq (3)	Dq	Muwf.
Length over buffers . . . . . m.	16.890	13.130	13.130	13.138	7.630
Wheel base . . . . . m.	10.000	8.000	8.200	8.000	4.000
Body, inside dimensions { length . . . . . m.	8.190(1)	9.088	12.294	11.092	6.493
Body, inside dimensions { width . . . . . m.	2.732	2.494	2.477	2.520	2.582
Tare . . . . . t.	31.7	20	17.5	20	13
Load . . . . . t.	8	6	8	6	...

Wagons.

Since the war, the wagon stock on the main lines has been made stronger, its carrying capacity increased, and its wheel base lengthened to improve its riding and allow the speed of goods trains to be raised.

Metal framing has been used in place of wood, and the buffing and draw gear strengthened. The ends of the older vehicles have been stiffened up too. The usual useful load today is 20 tons.

The fitting of the continuous brake to the ordinary goods stock — a major operation which took much time — makes it possible to speed up the goods trains, the maximum speed having been increased to 60 km. (37.3 miles) an hour already. When, during 1934, all the stock will be fitted with the continuous

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(1) Plus a post office compartment 5.10 m. (16 ft. 9 in.) long.

(2) Six-wheeled. Alsace Lorraine Railways only.

(3) Non-standard types, on the Paris-Orleans and State Railways only.

(1) Excluding a large number of special wagons (tank wagons, isothermic wagons, etc...) built with the same frame.

(1) Two of these vehicles are now in ser-vice.

Fig. 15. — 20-ton standard high-sided wagon.

brake, the speed limit will be raised to 70 km. (43.5 miles) an hour.

Standard wagons. — Twenty tons is the carrying capacity selected for most of the ordinary goods standard stock of the French railways, consisting of four-wheeled wagons with 4.50-m. (14 ft. 10 in.) wheel base, complying with the international regulations. As from 1919, all 20-ton wagons have been ordered to this design. At the present time the railways own more than 57 000 (1).

The leading dimensions of these wagons are :

		TTuw high-sided.	NNTouw flat.	KKuw covered.	REMARKS.
Inside body dimensions	length . . . m.	6.722	8.140	7.290	The covered wagons are fitted with the Westinghouse compressed air brake with « passenger-goods » triple valves so they can be formed in express parcels trains.
	width . . . m.	2.570	2.580	2.600	
	height . . . m.	1.410	0.500	2.470	
Floor area	m²	17.27	23	19	
Tare	t.	10.200	9.8	11.3	

The railways have also taken delivery of 1 900 forty-ton bogie wagons of the O.C.E.M. standard design. The tare is slightly over 20 tons. The load is limited to 40 tons through the maximum axle load of 16 tons accepted by the European railways. These wagons were designed, as regards bogie and underframe, to carry 52.5 tons.

The leading dimensions of the standard 40-ton wagons are as follows :

		High sided.	Flat.		
Length over buffers	m.	11.850	19.690	23.690	16.130
Distance between bogie centres	m.	6.850	14.000	18.600	10.500
Inside body dimensions — length	m.	10.710	18.354	22.354	14.854
Inside body dimensions — width	m.	2.642	2.120	2.130	2.750
Inside body dimensions — height	m.	1.845	9 stakes of 0.570	10 stakes of 0.570	10 stakes of 0.565
Floor area	m²	28.3	30.09	47.61	30.84
Tare	t.	20	20.1	22.9	19

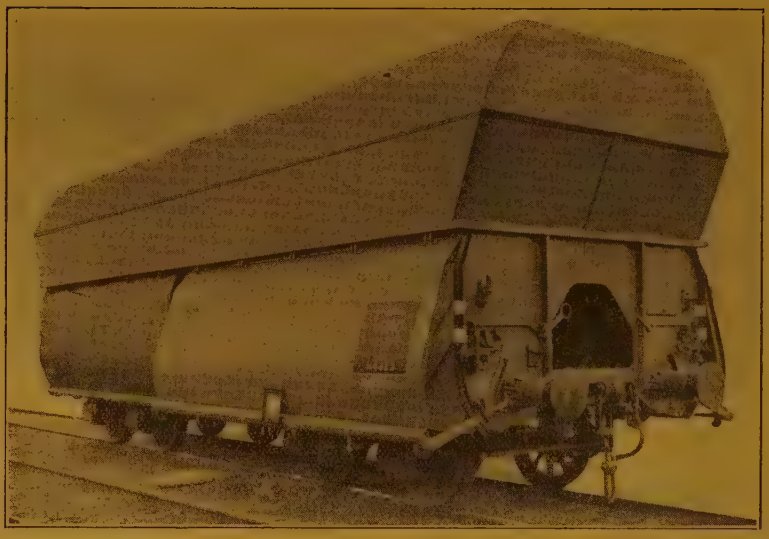


Fig. 17. — 60-ton self-discharging high-sided wagon, Nord Railway.

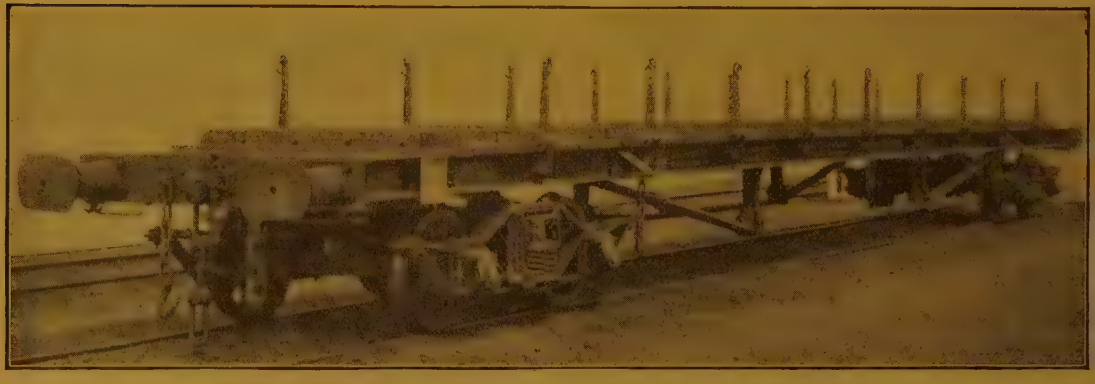


Fig. 16. — 40-ton standard flat wagon for loads up to 18.50 m. (61 feet) long.

The standard designs also include a 4-wheeled vehicle with 5.90-m. (19 ft. 4 1/4 in.) wheel base for vegetable traffic. The standardisation of the French rolling stock has been based on standard designs common to all railways, which can be altered as soon as an improvement is found necessary. This system, by its flexibility, avoids the usual defect of excessive standardisation resulting in the stabilisation of the original types for long periods. It enables the stock to be kept constantly up-to-date by fitting all improvements as and when found necessary in practice, or suggested by general engineering developments.

Miscellaneous wagons. — In addition to the standard stock the railways own high-capacity wagons such as the self-discharging high-sided bogie wagons of the Nord which have a carrying capacity of 60 tons, for a tare of 19 tons, the 50-ton high-sided bogie wagons of the Est and many high-sided wagons on the other lines. The 50-ton wagons being built for the Alsace-Lorraine Railways for bulk grain transport may be mentioned in this connection. Most of these high-capacity wagons exceed the allowable maximum axle load of 16 tons and are worked over the strengthened lines only.

Besides their high-capacity units, the railways own many isothermic or refrigerated wagons, as well as wagons for special purposes.

The Paris-Lyons-Mediterranean, for example, have designed a number of 6-m. (19 ft. 8 1/4 in.) wheel base wagons for carrying early vegetables (1), to a reduced loading gauge suitable for running in England and in fast trains on all Continental standard gauge lines.

The O. C. E. M. has also designed wagons for carrying early vegetables, which can run in France and England, and by changing wheels and axles, in Spain.

Rolling stock maintenance in the works and shops.

Rolling stock maintenance is a very important subject but it will be mentioned here very briefly as it does not come directly within the limits of an article dealing with the *structural* developments of the rolling stock.

However, we must mention that, since the war, the railways have done much work on the scientific reorganisation of rolling stock repairs in their shops.

They have laid out their available land and modernised their methods on modern principles, as used in private industry, each railway according to its ideas and needs.

The fundamental change may be said to be in dividing the shop work as between the preparatory work, the executive work, and the inspection.

Specialisation of the staff and even the works in each of these divisions, and especially so far as the actual carrying out of the repair work is concerned, has been carried very far (for example the adoption of the belt system) and has given remarkable results as regards efficiency and quantity of output.

The staff have been given an interest in the output by means of special premiums and these have produced the desired results.

The new methods have halved the time engines are out of service (35 days instead of 70). At the present time heavy repairs including a thorough repair to the engine and heavy boiler repairs take 19 days.

Mechanical improvements in details and careful inspection — systematic as a rule — of the parts when giving them their periodic overhaul have made it possible to increase the distance run by the engines from 60 000 km. (37 300 miles) in 1913, to 75 000 km. (46 600 miles) and even 90 000 km. (56 000 miles) for some engines in 1933, in spite of the heavier use made of them.

Then too the tool equipment, in the sheds and in the shops, has been modernised in accordance with the latest practice.

The repairs of electric locomotives have been organised on equally scientific lines, and the work is done more quickly. General overhauls of the locomotives and rail motor coaches which are given after about 120 000 km. (75 000 miles) are now taking only 6 days without using spares.

This examination of the principal lines of the evolution of French rolling stock since the war shows that these railways have kept in the forefront of technical progress and at the same time have

(1) Two of these vehicles are now in service.

adapted themselves to the changes in the economic situation.

The French rolling stock entirely renewed in all its sections since the war, thanks to the great effort made and the tenacity displayed, reflects the greatest honour on the railways.

It has enabled them to give the passengers greater safety and comfort, with additional facilities for faster travel. It has enabled them to speed up, in recent years, all their traffic in a very noticeable manner.

J. R.

[621 . 138 .5 (.436) & 625. 26 (.436)]

Austrian Federal Railways Workshops Department Reorganisation and Development,

by F. STRAUSS, Vienna.

Foreword.

The State-administered Austrian Federal Railways, on the 1st October 1923, were made into a separate financial undertaking. This date marks the beginning of reorganisation. The worn-out condition of the stock, as the result of the world war, could only be made good gradually owing to the lack of money in the post-war years, and the repair shops suffered from the same cause. Then too, as it was not definitely known what stock the Austrian Federal Railways would have left them for use on their own lines, it was possible neither to reform nor to standardise systematically the rolling stock as early as 1923. Only in 1925, after the stock had been divided up, was it possible to draw up the breaking up and renewal programmes. The carrying out of these programmes, with improved maintenance of the old stock left, has been the principal work the main shops have undertaken.

Changes in the stocks of locomotives and other power-driven vehicles.

The number of locomotives was 2 731 on the 1st October 1923. After the Austrian lines of the Südbahngesellschaft were taken over on the 1st January 1924, this number had grown to 3 278. The subsequent changes in the stock are shown in table 1.

TABLE I.

Austrian Federal Railways locomotive and railcar stock.

Power driven vehicles.	1.X. 1923	1.I. 1924	1.I. 1925	1.I. 1926	1.I. 1927	1.I. 1928	1.I. 1929	1.I. 1930	1.I. 1931	1.I. 1932	1.I. 1933	1.I. 1934
Steam locomotives.	2 667	3 201	2 894	2 607	2 559	2 630	2 478	2 324	2 218	2 240	2 085	2 084
Electric locomotives	48	50	77	91	112	125	154	192	196	209	221	221
Steam rail motor coaches . . .	3	3	3	2	1	1	1	—	—	—	—	—
Electric rail motor coaches . .	13	24	24	24	22	22	21	25	27	27	27	27
Internal - combustion - engined rail motor coaches	—	—	1	3	4	13	13	14	17	17	20	52
Total	2 731	3 278	2 999	2 727	2 698	2 791	2 667	2 555	2 458	2 493	2 353	2 384

When the rolling stock of the old Austro-Hungarian Monarchy had been divided up, the Austrian Federal Railways were left with 134 types of steam and 13 types of electric locomotives.

Most of the steam engines were old types extravagant in coal consumption. The old and inefficient steam engines have been eliminated and the number of types reduced to 47. Five new types have been introduced in replacement of those withdrawn. As a result of electrification the number of types of electric locomotives is now 20. At present there are 22 types of vehicles fitted with internal combustion engines.

The change in traffic conditions in recent years, and also financial reasons and the need for meeting road competition made it necessary to accelerate the trains and increase their frequency, which resulted in the introduction of new motor vehicles. Thus during 1933, three types of vehicles with internal combustion engines were introduced, two with diesel engines and one petrol.

Through the decline in traffic in the second half of 1930, a number of locomotives in working order for which there was no immediate need were stabled. During the following years, more and more engines in working order and others which required extensive repairs were withdrawn from traffic.

Coaching vehicles and wagons.

The stock of passenger coaches, post office vans, and parcels vans has increased, from 7 090 in October 1923, to 7 898, and the goods and service wagons from 38 188 to 39 232. The serious changes in the stock figures are due to old vehicles being withdrawn and new vehicles added to the stock, etc. As regards the increases, 1928 was a noteworthy year, as 6 000 vehicles were added that year. In the case of new passenger vehicles all-metal construction has been adopted as a principle.

All new coaches, wagons, and rail motor coaches have been built by Austrian firms on the principles of standardisation and interchangeability.

The number of the different types and classes of vehicles will give us an idea of the multitude of designs of the stock. The passenger carriages, post office, and parcels vans include 276 groups and 20 classes, and the goods wagons 122 groups and 29 classes.

Modification in the regulations dealing with repairs.

The regulations governing rolling stock repairs and their examination were adapted in 1923 to the altered working conditions. The principle adopted was to bring the stock, and especially the locomotives, in the main shops for repairs more frequently. The reason for this was to reduce the repair costs, to improve the state of repairs, and to keep the main shops working at a uniform rate, at the same time taking away work from the outlying repair shops. At the present time, heavy repairs are only done at the main shops, to the whole of the locomotives, with the single exception of the electric locomotives which are to some extent dealt with in the ordinary maintenance shops, owing to the Linz main repair shops being inconveniently placed as regards the electrified lines in Western Austria. Thanks, to the wide interchangeability of parts, the work done in the outlying repair shops on the electric locomotives is limited. The interchangeable parts are repaired at Linz.

Tables II to IV below give particulars of the new repair periods for locomotives and carriages.

TABLE II.

Steam locomotive repairs.

Class of repairs.	Designation.	Period.	Remarks.
Heavy repairs.	HV	Every 6 years or every 5 years for steel, or steel and copper, fireboxes.	...
Lifting.	A	After a maximum of 100 000 km. (62 000 miles) for express, passenger and goods engines, and 150 000 km. (93 000 miles) for shunting engines.	Raised as an experiment for 2 years to 130 000 km. (80 800 miles), and for some classes of engine to 150 000 km. (93 000 miles).
Light repairs.	T	According to each case, or owing to defects found on examination.	Includes repairs carried out at the fixed annual inspections.
Running repairs.	L	...	Includes repairs carried out at the monthly, bi-monthly, quarterly or half-yearly inspections.

TABLE III.

Repairs of electric locomotives.

Class of repairs.	Désignation.	Period.	Remarks.
Heavy repairs.	G	After 150 000 km. (93 000 miles) to 200 000 km. (124 000 miles) for express, passenger and goods engines.	...
Light repairs.	T	According to each case or when defects are found.	Includes repairs done at quarterly, half-yearly, or annual examinations.
Running repairs.	L	...	Includes repairs at bi-monthly and monthly examinations.

TABLE V.

Period between carriage and wagon repairs.

Use of vehicle. Class of vehicle.	Period between repairs.	Remarks.
In express and passenger trains of maximum speeds of : over 90 km. (56 miles).	6 months.	
over 70 km. (43.5 miles).		
up to 90 km. (56 miles).	One year.	
up to 70 km. (43.5 miles).	18 months.	
In goods trains	3 years.	8-wheeled goods wagons which receive an intermediate repair after 18 months.
On narrow-gauge lines in passenger train service .	2 years.	
Standard-weight wagons, steam heating boiler wagons, travelling cranes, snow ploughs, transhipwagons	1 year.	
Gas-oil tank wagons	2 years.	
Tool and ballast wagons, and service wagons in breakdown trains	3 years.	
Service wagons	4 years.	

Incorporation of the workshop department in the undertaking as a whole.

Before the undertaking known as the Austrian Federal Railways was set up, the whole of the repair work came under the area managements which in turn were responsible to the Federal Minister of Commerce and Transport. The Operating, Traction and Workshops Departments were grouped under the Transport section of the Ministry. The workshops department of this section controlled the whole of the rolling stock maintenance service.

The whole of these functions devolved upon the General Management of the Austrian Federal Railways from the 1st October, 1923. This smoothed the way for simplifying the elaborate administrative machinery in the workshop service and for eliminating the different headquarters in this branch of the railways. It thereby led to uniform management.

The main workshops were placed under the immediate control of the shop management. The field of action of the shops was clearly defined and, as a result, they became more self-contained. The higher management and the supervision of the services were brought under the workshop headquarters which on taking over the locomotive running department and the outlying repair shops was made, in 1930, the Mechanical Engineering Department.

The workshop service is independent of the rest of the undertaking except in so far as it is limited by general considerations. Amongst these may be mentioned the conditions of service of the staff, the general regulations as to wages, salaries, promotion, and the allocation of credits. The purchase of constructional materials is not under the Mechanical. Engineering Department, but is centralised for all branches of the railway under the Stores Department which also controls the main stores.

Centralisation of the workshops service.

In 1923, the Austrian Federal Railways had 14 workshops. Steam locomotives were repaired in 12, the electric locomotives in 1, the passenger carriages in 12, and the goods wagons also in 12 shops.

By rationalisation up to 1933 included, the workshops at Vienna-Western station, Graz-Koflach station, Graz-Andritz station, the Südbahn shops at Vienna, the Jedlesee, Salzburg, Feldkirch and Innsbruck shops were suppressed. As a result there are now only 5 main shops. The electric locomotives are dealt with in 1 of these (Linz), the steam locomotives in 3 (Floridsdorf, Linz, and Knittelfeld), the internal combustion-engined vehicles in one (St. Pölten), the passenger coaches, post office and parcels vans in 2 (Simmering, and St. Pölten), and the goods wagons in 3 (Floridsdorf, St. Pölten and Knittelfeld).

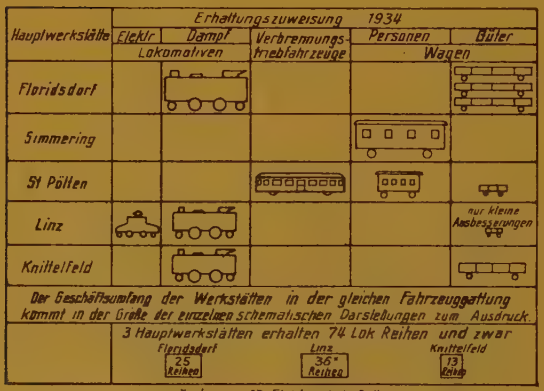


Fig. 1.

Figure 1 shows the distribution of the vehicles to be repaired as amongst the different works.

Nine shops and 28 repair points have been closed down. The result is that there is a main shop per 1 162 km. (722 miles) instead of one per 600 km. (373 miles) of line operated. These rationalisation measures deserve the greater appreciation as everyone knows how much a railway workshop at any given place means to the population and how difficult it is once such a workshop has been set up to do away with it.

Reorganisation of the shop methods.

As a result of the financial position of the Austrian Federal Railways, little money was available for reorganising the shop methods. Another difficulty was that practically all the staff was permanent. A start was made at Knittelfeld, to which shop the explanations below refer.

When the new methods were first introduced the wages were higher than those in private works and it was not possible therefore to get the men interested in the new methods by the attraction of increased earnings. A psychological means consisting of stimulating the rivalry between the different shops, was resorted to. The idea of emulation was extended even to the speed with which the repairs are completed. The object was attained by means of detailed programmes showing the time each job must be done in, if the vehicle is to be repaired quickly.

The reorganisation principle, first applied to the Knittelfeld shop, is the substitution for the craftsman's individual work, determined in each particular case, of a series of methodical and un-

Explanation of German terms :

Hauptwerkstätte = Main shops. — Erhaltungszuweisung 1934 = Distribution of maintenance work, 1934. — Elektr-Dampf-Lokomotiven = Electric-Steam-locomotives.— Verbrennungstriefahrzeuge = Internal combustion engined vehicles. — Personen Wagen = Carriages. — Güter Wagen = Goods wagons. — Nur kleine Ausbesserungen = Light repairs only. — Der Geschäftsunmfang... zum Ausdruck = The extent of the work done in the different shops on the same classes of vehicle is shown by the dimension of the diagram. — 3 Hauptwerkstätten... und zwar = 3 main shops deal with 74 classes of locomotives, namely. — Reihen = Classes. — Hiervon 12 Elektrolok Reihen = Including 12 classes of electric locomotives.

changing operations, which, in conjunction with the most up to date shop methods, avoid the former losses.

The vehicles being, however, in widely differring services, some on level lines and others in hilly country, are not subjected to the same fatigue, and the degree of wear varies so much that, if the repairs to be done are laid down too rigidly, the cost inevitably would increase. This already limits the degree of specialisation, the quantity of spares and interchangeable parts, and the application of the belt system.

At the same time the degree of wear and the repairs required to each detail have had to be ascertained so that the repair programmes show slight variations from the standard. The general working programme, in other words, is adapted to each individual case.

Mass production and mass repair methods have been developed to the fullest extent in order to obtain the financial savings resulting from such methods. Interchangeability, and especially mass production of semi-finished parts for stock has the same object in view.

The breaking up of the work to be done into the detailed operations involved at the same time the division of the old inclusive prices, that is to say the contract rates for a more or less clearly defined group of jobs. These contract rates had to be divided up sufficiently to ascertain the value of each job as a whole and of each individual operation, the different degree of wear also being taken into account. This subdivision had, on the other hand, to be kept within limits so that the distribution of the work and the accountancy should be as simple as possible. The number of time rates in force in the Knittelfeld shops has increased from 3 000 to some 30 000.

In order to simplify and speed up the distribution of the repair work, printed forms have been drawn up for each group of parts, the time for each individual task being often printed in. The issuing clerk first of all only marks the operation the job in question involves, or in some cases the number of parts to be repaired, from which the total time to be taken can be calculated. A similar procedure has been followed in purchasing materials. For each group of detail parts, printed lists of the materials required have been provided, and on these the materials needed are marked off when the job is started.

The time rates have been arrived at by timing the jobs. Since this method was introduced at the beginning of 1926 some 30 000 time allowances have been arrived at. The timings are made by foremen specially instructed both theoretically and practically.

The times taken in the Knittelfeld and Linz shops have been applied in the other shops for the same work, adjusted if necessary to meet the local working conditions. In this way, the times were determined very closely and applied as widely as possible. The rate of working is thereby accelerated. At the same time as the working times were arrived at with such care, the time spent at work was recorded by clocks. The starting and finishing times are noted, not only for each job but also for the gangs which cover the bulk of the work. A special card had to be provided for this case and special steps taken to book in. The cards are stamped by the man or the chargehand. Abuses are prevented by the watchfulness of the time keeper and work inspectors. The times recorded are brought to account when calculating the balance by calculating machines.

In place of the old contract rate, a system of premiums adapted to meet the needs for economy in management has been introduced. This system guarantees the workman an individual return corresponding to the work he has done. It also provides the base for cal-

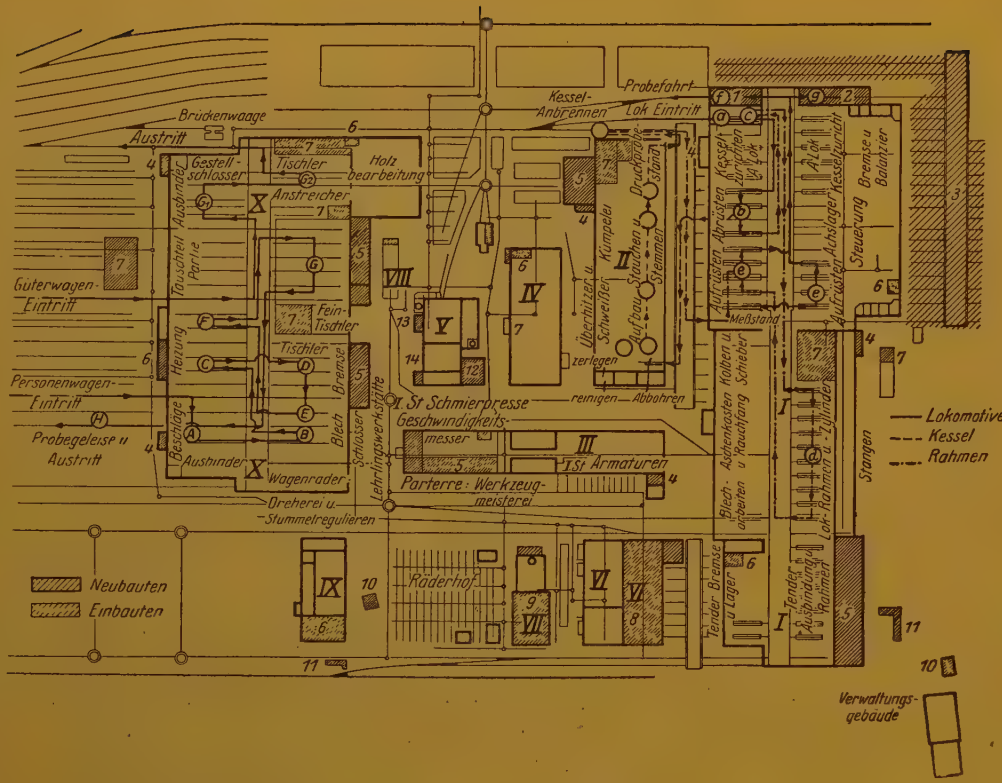


Fig. 2. — General layout and routing of work in Knittelfeld main shops.

I. Locomotive and tender erecting shop.
II. Boiler shop.
III. Lathes and tool room.
IV. Smiths shop.
V. Boilerhouse and engine room.
VI. Wheel, pipe and copper smiths shop.
VII. Welding and white-metalling shop.
VIII. Bosch.
IX. Tinsmiths.
X. Carriage and wagon shop.

1. Lighting up shed.
2. Locomotive paint shop.
3. Stock yard with traverser.
4. New closets (6).
5. Lavatories and dressing room.
6. Offices.
7. Building materials.
8. Tender repair shop converted into a wheel shop.
9. Tyre shrinking on shop turned into main welding shop.
10. Time recording clocks. In.
11. Cycle shed.
12. Electric trucks and battery charging station.
13. Water tank and pumps.

Locomotive repairs.

a) Preparatory stripping.
b) Stripping down.
c) Spray-cleaning of frames.
d) Frame and cylinder work.
e) Finishing off.
f) Lighting up.
g) Painting after trial run.

Carriage and wagon repairs.

A. Lifting and underframe.
B. Stripping outer panelling.
C. Strippinp body.
D. Refitting body.
E. Repairing outer panelling.
F. Roof.
G. Painting.
G¹. Lifting, underframe, stripping off wooden bodies.
G². Erecting bodies and paint shop.
H. Inspection and passing out tracks.

Explanation of German terms :

Kessel = boiler. — Rahmen = frames. — Güterwagen = gooods wagons. — Personenwagen = passenger stock. — Eintritt = incoming. — Austritt = outgoing. — Neubauten = new work. — Umbauten = rebuilds. — Brückenwagen = weighbridge. — Gestellschlosser = fitters. — Ausbinder = strippers. — Tauschteil Partie = spare parts. — Heizung = heating. — Beschläge = fittings. — Tischler = joiners. — Anstreicher = painters. — Feintischler = cabinet makers. — Wagenräder = wheel shop. — Dreherei u. Stummelregulieren = Lathes and journal lathes. — Holzbearbeitung = wood working shop. — Bremse = brake. — Blech Schlosser = tinsmith. — Schmierpresse = mechanical lubricators. — Geschwindigkeitsmesser = speed indicators. — Lehrlingswerkstatt = apprentice shop. — Werkzeugmeisterei = tool room. — Raderhof = Wheel park. — Kessel anbrennen = lighting up house. — Probefahrt = trial run. — Lok. eintritt = locomotive incoming road. — Überhitzer = superheaters. — Schweisser = welders. — Kümpelei = press shop. — Stauchen u. stemmen = caulking. — Druckprobestand = boiler pressure test. — Bremse u. Lager = brake and axle boxes. — Ausbindung u. Rahmen = lifting, and frame. — Blecharbeiten = plate work. — Aschenkasten u. Rauchfang = ash pans and smoke boxes. — Kolben u. Schieber = pistons and valves. — Aufrüsten = erecting. — Abrüsten = stripping. — Kesselzurichten = Preparatory work on boilers. — Achslager = axle box brasses. — Lok. Rahmen u. Zylinder = frames and cylinders. — Steuerung = valve gear. — Bremse u. Balanzier = brakes and equalisers. — Verwaltungsgebaüde = administrative offices. — Stangen = rods. — Zerlegen = taking down. — Reinigen = cleaning. — Abbohren = boring.

culating times for doing the different jobs.

Accountancy.

The whole of the accountancy has been reorganised in order that the individual accounts shall be correct. Individual costs of repairs to locomotives were already in existence. Individual vehicle costs were then introduced, the exception being small running repairs to goods wagons, which are charged by batches each day per track. In the same way, each operation in connection with stocking or repairing spare parts and every individual operation is calculated and booked in when the order is placed. Then too the costing has been reorganised. The costs have been divided into 25 headings as regards main charges and 66 subsections of part costs dealt with in 77 costing sections.

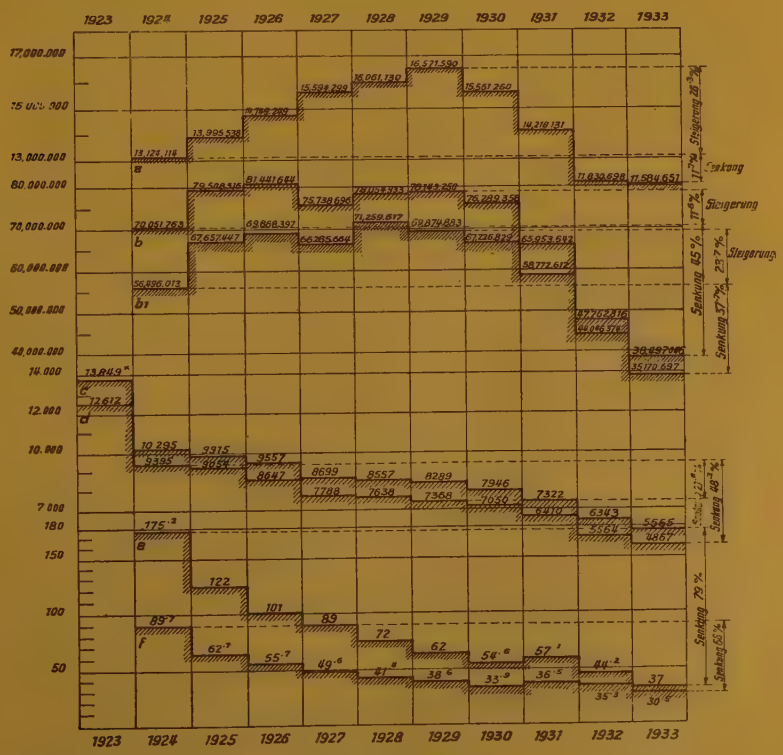
Division of the work.

A distinction is made between repairs and renewals. The former are dealt with in the locomotive erecting shops and the carriage repair shops, the latter in subsidiary works.

The old practice of grouping the men into gangs has been radically altered. Whereas formerly large gangs of men

TABLE V.

Workshops Department. — Typical numerical data.



a) 1 000 gross tonne-kilometres.

b) Total expenditure of the main workshops department.

b') Rolling stock repairs expenses.

c) Total staff in the workshops (yearly average).

* Maximum staff in 1928.

d) Number of workmen in the workshops (yearly average).

e) Number of days a locomotive is out of service for a heavy repair.

f) Number of days a locomotive is out of service for a repair including lifting.

Note. — Steigerung = increase. — Senkung = decrease.

were responsible for several vehicles and did all the repairs needed, the new gangs are so organised that each one of them only deals with one kind of work. How far this specialisation should be carried is decided by local considerations and the amount of work to be done in the particular shop in question.

As a general principle, the following work is not included in the repair work proper :

1. transport work,
2. stores, and
3. tools.

1. Transport. — The transport service includes all work involved in transporting all construction and running department stores, and all parts used in connection with the work inside the shop. It is divided into bulk and detail transport. Electric trucks are used and are operated to timetable to suit the service. All pathways are concreted.

2. Constructional materials. — The stores are independent of the shops and as they are some distance away it was considered it would be expensive to make individual deliveries of parts. Shop stocks were therefore instituted in the shop sections to act as distributing stores. These stores draw their supplies from the main stores, distribute them to the shops, keep up the stock cards, and also the ledger cards, and collect and dispose of scrap and look after the stock of interchangeable and semi-finished parts.

3. Tools. — A central tool shop has been set up in each works. This tool shop controls tool rooms in each section, which latter not only issue tools but make the special tools needed and keep the whole of the tool equipment in good repair.

At the same time that the gangs were redistributed, the organisation in the shops had to be changed. Whereas formerly the vehicles remained in position until the repairs were completed, under the new arrangements the vehicles or their constituant parts move from gang to gang. Figure 2 shows the path the vehicle takes in the Knittelfeld shops; this figure also shows the new buildings and reconstructed buildings made necessary by the new methods.

In the reorganised shops the principle enforced is that no work is done without an order. The fixed path the detail parts and the relative documents follow is a guarantee of the accuracy of the accounts and facilitates the control. All accountancy work in the shops is done by machine whenever possible.

Results obtained through the reorganisation of the services.

In spite of the unfavourable conditions from a repair point of view of the locomotives dealt with at these two shops (rack locomotives, most of the engines requiring new cylinders, etc.), the time required for the repairs has been reduced by 30 %, although the times were already short when the reorganisation was taken in hand. The results obtained at Knittelfeld were so good that the other shops were reorganised on the same lines.

Table V shows the successful results of rationalising the repair shop methods. The growth of traffic increased the demands on the repair shops, but in spite of this the number of men has been greatly reduced and the times for repairing the vehicles much shortened, thereby placing more vehicles at the disposal of the operating department.

Unfortunately, the economic crisis and as a consequence the falling off of traffic and the reduction of receipts prevented the proposed reorganisation from being carried further. Furthermore the shops had less work to do and therefore the results obtained whilst the traffic increased — up to 1930 — could no longer be got.

[621.132.3 (.492) & 621.132.6 (.492)]

The heaviest tank locomotive in the world,

by F. S. DORTMUND.

(Die Lokomotive.)

The Netherlands Railways ordered, in 1930, from Messrs. Henschel & Sohn, of Cassel, a 4-8-4 four-cylinder superheated steam goods tank locomotive which gave such good results from all points of view that ten engines of the same design were purchased from the same firm, and subsequently several engines of the same class were built by the « Berliner Maschinenbauanstalt vorm. Schwartzkopff », to Messrs. Henschel's drawings.

As it weighs 126.4 t. (124.4 Engl. tons) in working order, this GTO3 type class 6300 engine of the Netherlands Railways can be taken as the heaviest of its kind. For comparison, the old T3 Prussian engine weighed 30 t. (29.5 Engl. tons).

The Dutch locomotive has bar frames, the main plates being 100 mm. (3 15/16 inches) thick, and the boiler has a Belpaire firebox.

The outside piston valves are driven by rocking levers by the inside piston valve spindles. The crank axle is a single-piece forging. The flanges of the 4th and 5th pairs of wheels are reduced in thickness by 10 mm. (3/8 inch). All four cylinders drive the one pair of driving wheels. 2 two-stage air pumps are carried on the right hand footplate. To prevent smoke drifting down onto the spectacle glasses the engine has been fitted with side screens like those now being generally fitted on many railways.

An interesting feature of these engines is that the motion, valve gear, cylinders, boiler and bogies are exactly the same, and therefore interchangeable with the same parts on the 4-6-0 type four-cylinder superheated steam express engines of class PO4, series 3900, designed and supplied by Messrs. Henschel to Holland in 1929. The coupled wheels, of course, are not the same. The GTO3 is mainly used for working fast goods trains over the main lines. Owing to the relatively large wheel diameter, it will be possible to use the engine for working passenger trains the maximum speed of which is fixed at 90 km. (56 miles) an hour.

The leading dimensions of the two types are given in figures 1 and 2 below.

A photograph of the PO4 engine mentioned above is also reproduced, in connection with the interchangeability of the principal parts. Messrs. Henschel have delivered 32 of these engines up to date, no other firm, so far as we know, having supplied any of this type. This engine can haul 670 t. (659.4 Engl. tons) i. e. 18 corridor carriages and attain a speed of 100 km. (62 miles) an hour. The PO4 can be considered as an addition to the many PO3 engines (4-6-0 four-cylinder superheated steam express engines weighing 73.1 t. [71.9 Engl. tons] in working order) which have been in service in Holland for many years. It works express trains over all the Company's main lines and is said to have met all the conditions specified.

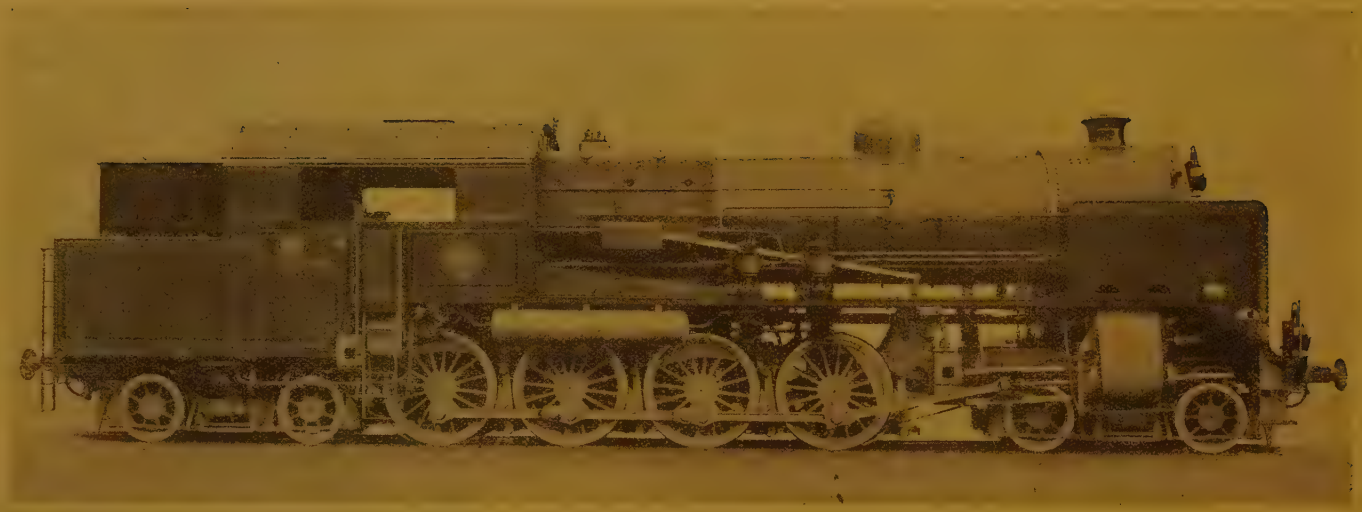


Fig. 1. — 4-8-4 four-cylinder superheated class GT03 series 6300 locomotive of the Netherlands Railways, built by Messrs. Henschel & Sohn, of Cassel

Cylinder bore (4)	420 mm.	*(16 1/2 in.)*
Piston stroke	660 mm.	*(26 in.)*
Wheel diameter carrying	930 mm.	*(3 ft. 5/8 in.)*
Wheel diameter driving	1.550 m.	*(5 ft. 1 in.)*
Wheel base rigid	5.250 m.	*(17 ft. 2 25/64 in.)*
Wheel base total	14.050 m.	*(46 ft. 1 in.)*
Boiler pressure	14 atm.	*(206 lb. per sq. inch.)*
Heating surface evaporative	167.2 m²	*(1800 sq. ft.)*
Heating surface superheating	54.0 m²	*(581 sq. ft.)*
Heating surface total	221.2 m²	*(2381 sq. ft.)*
Grate area	3.16 m²	*(34 sq. ft.)*
Water	14 t.	*(3080 Br. Gallons)*
Coal	4.5 t.	*(13.8 Engl. tons)*
Weight empty	101.6 t.	*(100 Engl. tons)*
Weight in working order	126.4 t.	*(124.4 Engl. tons)*
Weight adhesive	72.0 t.	*(70.9 Engl. tons)*
Maximum speed	90 km./h.	*(56 miles/h.)*
Maximum tractive effort (0.75 *p.*)	15.8 t.	*(15.55 Engl. tons)*
Smallest radius of curve negotiated	200 m.	*(10 chains)*

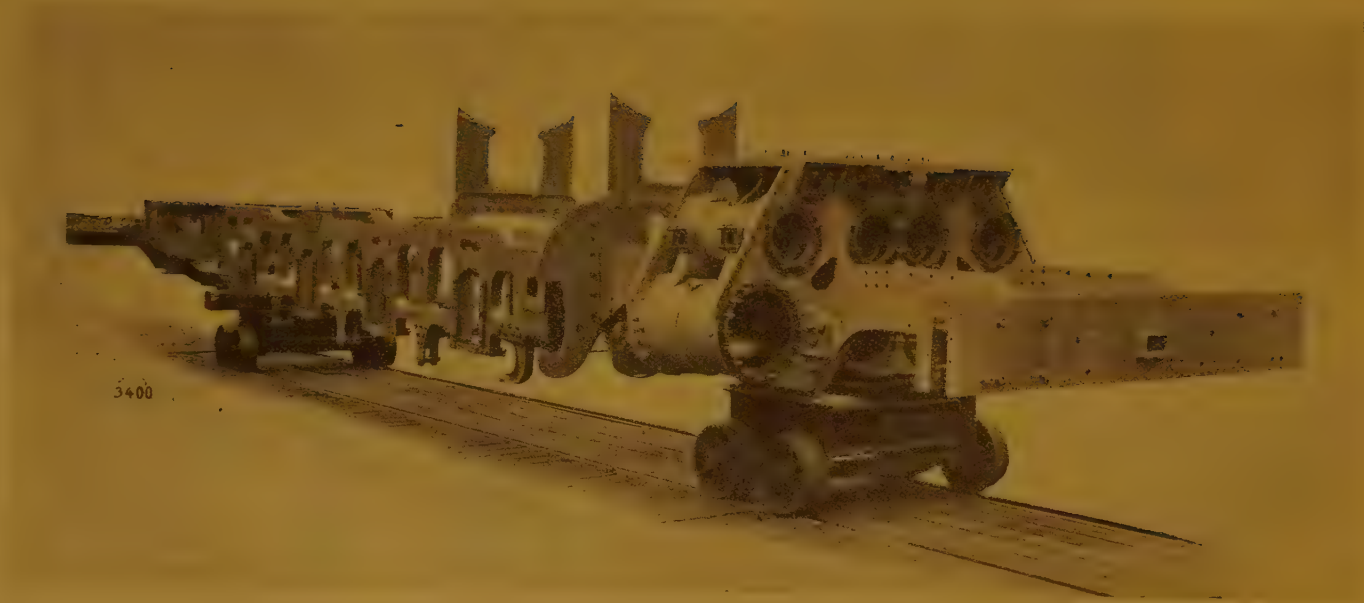


Fig. 2. — Bar frames and cylinders of the 4-8-4 four-cylinder tank engine.

Fig. 3. — 4-8-0 four-cylinder superheated steam express engine, class P04 series 3900, of the Netherlands Railways.

Engine.

Cylinder bore (4)		420 mm.	*(16 1/2 in.)*
Piston stroke		660 mm.	*(26 in.)*
Wheel diameter	carrying	930 mm.	*(3 ft. 5/8 in.)*
	driving	1.850 m.	*(6 ft. 1 13/16 in.)*
Wheel base	rigid	4.500 m.	*(14 ft. 9 5/32 in.)*
	total	9.350 m.	*(30 ft. 8 1/8 in.)*
Boiler pressure		14 atm.	*(206 lb. per sq. in.)*
Grate area		3.16 m²	*(34 sq. ft.)*
Heating surface	evaporative	167.2 m²	*(1800 sq. ft.*
	superheating	54.0 m²	*(581 sq. ft.)*
	total	221.2 m²	*(2381 sq. ft.)*
Weight	empty	78.0 t.	*(76.8 Engl. tons)*
	in working order	84.0 t.	*(82.7 Engl. tons)*
	adhesive	55.0 t.	*(54.1 Engl. tons)*
Maximum tractive effort (0.75 *p.*)		13.2 t.	*(13.0 Engl. tons)*
Smallest radius of curve negotiated		140 m.	*(7 chains)*
Maximum speed		100 km./h.	*(62 miles/h.)*

8-wheeled rigid wheel base tender.

Diameter of wheels		1.100 m.	*(3 ft. 7 5/16 in.)*
Rigid wheelbase		4.800 m.	*(15 ft. 9 in.)*
Water		28 t.	*(6160 Br. gallons)*
Coal		6 t.	*(5.9 Engl. tons)*
Weight	empty	29 t.	*(28.5 Engl. tons)*
	loaded	63 t.	*(62 Engl. tons)*

MISCELLANEOUS INFORMATION.

[656. 222.1 (.42)]

1. — High-speed possibilities with steam locomotives.

(100 m. p. h. reached on the London & North Eastern Railway).

By courtesy of Mr. Gresley, Chief Mechanical Engineer, London and North Eastern Railway, we give hereafter particulars of the passing times, speeds, etc., of a trial made on Friday, 30th November, between King's Cross and Leeds. The engine used for the purpose was No. 4472, *Pacific* type, « Flying Scotsman », which was exhibited at Wembley in 1925.

This engine was taken out of ordinary traffic without special preparation. The photograph, figure 1, shows this engine which, since it was built, has run 653 071 miles, and since it was last through the shops for repairs, 44 176 miles.

Figure 2 is a gradient section of the line between Peterborough and Grantham, which also gives the speeds in both directions.

Whilst the speed of 100 m.p.h. was reached on the return journey, the most interesting feature of the run was the speed attained up the long gradient of 1 in 200 between Peterborough and Stoke.

Fig. 1.

Principal characteristics and dimensions :

Gauge of track		4 ft. 8 1/2 in.
Cylinders	diameter	20 in.
	stroke	26 in.
Driving wheel diameter		6 ft. 8 in.
Boiler	inside diameter	6 ft. 3 5/8 in.
	pressure	180 lb.
Firebox	outside length	9 ft. 5 1/2 in.
	outside width	7 ft. 9 in.
Diameter of tubes	(168)	2 1/4 in.
	(32)	5 1/4 in.
Length between tube plates		19 feet
Wheel base	driving	14 ft. 6 in.
	engine	35 ft. 9 in.
	engine and tender	60 ft. 10 5/8 in.

Weight in working order	bogie	17 t. 1 cwt.
	coupled	60 t. 0 cwt.
	trailing	15 t. 8 cwt.
	engine	92 t. 9 cwt.
	tender	62 t. 8 cwt.
Kind of fuel		Coal
Evaporating surfaces	tubes	1 880 sq. feet
	flues	835 » »
	firebox	215 » »
	total	2 930 » »
Superheating surface		525 sq. feet
Grate	length	70 15/16 inches
	width	83 3/4 inches
	area	41.25 sq. feet
Tractive power at 85 % boiler pressure		29 835 lb.
Factor of adhesion		4.5
Tender (8-wheeled corridor)	water	5 000 gallons
	coal	9 tons

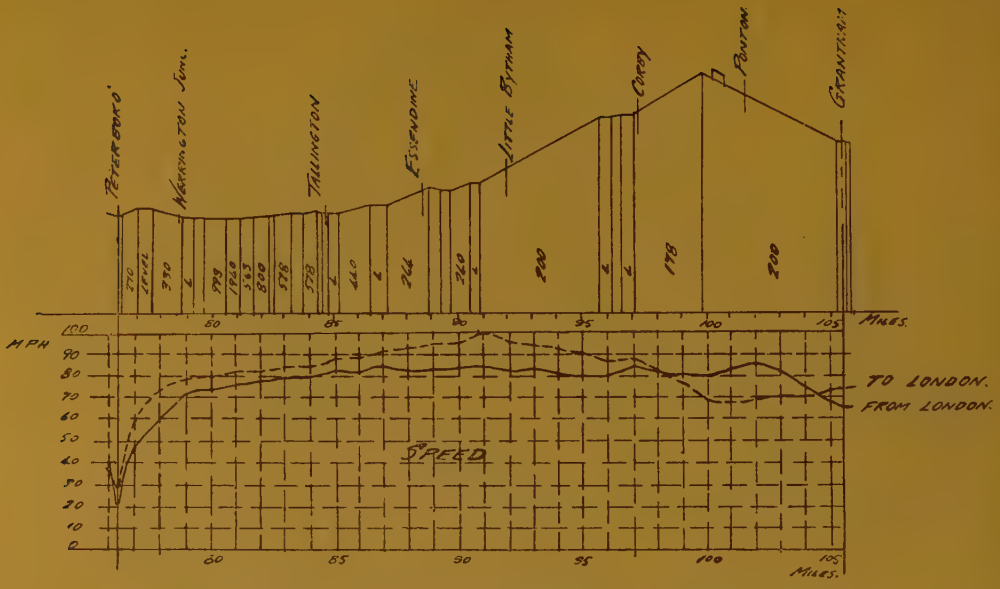


Fig. 2. — Performance of engine 4472 between Peterborough and Grantham, 30th November, 1934.

TEST BETWEEN KING'S CROSS & LEEDS.

November 30th, 1934. Vehicles : 4. Axles : 16. Tons : 145.

Miles from King's Cross.	Station.	Times.					Speed-miles per hour.		
		Booked.		Actual.			Passing.	Average between booking points (*)	Maximum attained between booking points (*)
		H.	M.	H.	M.	S.			
...	King's Cross	9	8	9	7	45	...		
2.3	Finsbury Park			9	11	45	55.5		
3.2	Harringay			9	12	40	61.0		
3.9	Hornsey			9	13	17	67.0		
4 7	Wood Green			9	14	4	70.0		
6.3	New Southgate			9	15	22	66.0	61.8	84.0
8.2	Oakleigh Park			9	17	7	66.5		
9.0	New Barnet			9	17	50	69.5		
10.4	Hadley Wood			9	19	5	68.5		
12.6	Potters Bar			9	21	0	70.0		
14.3	Brookmans Park			9	22	23	78.2		
17.5	Hatfield	9	27	9	24	45	81.5		
20.2	Welwyn Garden City . . .			9	26	50	64.5		
21.8	Welwyn			9	28	28	65.0	75.2	92.0
24.9	Knebworth			9	31	7	75.0		

(*) All speeds are taken from the dynamometer car records.

Miles from King's Cross.	Station.	Times.					Speed-miles per hour.		
		Booked.		Actual.			Passing.	Average between booking points (*)	Maximum attained between booking points (*)
		H.	M.	H.	M.	S.			
28.4	Stevenage			9	33	47	81.5		
31.7	Hitchin	9	38	9	36	5	91.5		
35.6	Three Counties			9	38	30	92.5		
36.9	Arlesey			9	39	25	94.5		
41.0	Biggleswade			9	42	10	92.0		
44.0	Sandy			9	44	6	89.5	89.3	95.0
47.4	Tempsford			9	46	20	90.5		
51.6	St. Neots			9	49	12	85.0		
55.8	Offord			9	52	5	83.0		
58.7	Huntingdon North	9	58	9	54	14	83.0		
63.4	Abbots Ripton			9	57	55	77.8		
69.2	Holme			10	2	12	80.5	74.8	83.0
72.5	Yaxley			10	4	40	74.5		
76.3	Peterborough North	10	14	10	8	20	21.0		
84.7	Tallington			10	16	10	82.5		
88.5	Essendine			10	18	50	83.0		
92.1	Little Bytham			10	21	30	81.5	75.8	86.0
97.0	Corby			10	25	5	85.0		
101.9	Great Ponton			10	28	40	85.0		
105.4	Grantham	10	40	10	31	20	61.5		
109.6	Barkston			10	34	58	75.0		
111.5	Hougham			10	36	25	77.0	79.4	90.0
115.3	Claypole			10	39	7	87.0		
120.0	Newark	10	51	10	42	22	86.8		
126.3	Carlton			10	46	55	82.0		
127.3	Crow Park			10	47	37	80.5	79.2	86.5
131.2	Dukeries Junction			10	50	40	73.0		
131.8	Tuxford			10	51	12	72.5		
138.6	Retford	11	7	10	56	27	67.6		
141.7	Sutton			10	59	0	79.6		
143.9	Ranskill			11	0	36	85.5	76.1	88.0
145.7	Scrooby			11	1	54	86.5		
147.6	Bawtry			11	3	13	82.0		
151.2	Rossington			11	5	50	85.0		
156.0	Doncaster	11	21	11	10	10	41.5		
159.9	Carcroft & Ardwick			11	14	20	68.5		
162.4	Hampole			11	16	20	76.5		
164.6	South Elmsall			11	18	0	81.5		
167.7	Hemsworth			11	20	27	78.0	69.5	84.0
170.3	Nostell			11	22	20	81.0		
171.8	Hare Park & Crofton			11	23	26	81.0		
174.1	Sandal			11	25	10	73.0		
175.7	Wakefield Westgate	11	39	11	27	11	42.5		
178.2	Lofthouse			11	30	4	41.5	49.6	54.0
180.0	Ardsley	11	45	11	32	23	53.5		
183.2	Beeston			11	35	30	62.0		
185.1	Holbeck			11	37	55	20.5	46.8	62.0
185.7	Leeds Central	11	53	11	39	40	...		
185.7	*King's Cross-Leeds*	*2*	*45*	*2*	*31*	*55*	...	*73.4*	...
				Average booked speed : 67.5.					

(*) All speeds are taken from the dynamometer car records.

TEST BETWEEN & LEEDS KING'S CROSS.

November 30th, 1934. Vehicles : 6. Axles : 24. Tons : 205.

Miles from Leeds.	Station.	Times.					Speed-miles per hour.		
		Booked.		Actual.			Passing.	Average between booking points.	Maximum attained between booking points.
		H.	M.	H.	M.	S.			
...	Leeds Central	2	0	2	0	8	...		
0.5	Holbeck			2	1	45	28.5	44.1	56.2
2.5	Beeston			2	4	25	54.0		
5.7	Ardsley	2	9	2	7	54	56.2		
7.5	Lofthouse			2	9	53	47.2	52.4	60.5
10.0	Wakefield Westgate	2	14	2	12	50	40.0		
11.7	Sandal			2	15	0	59.3		
13.9	Hare Park & Crofton			2	17	15	60 5		
15.4	Nostell			2	18	40	65.0		
18.0	Hemsworth			2	20	50	66.0	64.8	82.0
21.2	South Elmsall			2	23	35	79.2		
23.3	Hampole			2	25	12	80.0		
25.7	Carcroft & Ardwick			2	27	10	71.2		
29.7	Doncaster	2	32	2	31	7	40.0		
34.4	Rossington			2	35	25	75.0		
38.0	Bawtry			2	38	14	83.5		
40.0	Scrooby			2	39	30	88 0	76.8	88 0
41.8	Ranskill			2	40	50	85.5		
44.0	Sutton			2	42	24	83.6		
47.1	Retford	2	47	2	44	40	81.6		
53.9	Tuxford			2	49	50	81.0		
54.5	Dukeries Junction			2	50	20	81.2		
58.4	Crow Park			2	53	9	81.8	80.3	83.0
59 4	Carlton			2	53	50	82.0		
65.7	Newark	3	2	2	58	35	76 4		
70.4	Claypole			3	2	20	76.0		
74.2	Hougham			3	5	20	75.0	73.9	79.5
76.1	Barkston			3	6	50	71 0		
80.3	Grantham	3	14	3	10	26	74.4		
83.8	Great Ponton			3	13	20	68.8		
88 7	Corby			3	17	20	86.8		
93.6	Little Bytham			3	20	33	96.0	80.7	100.0*
97.2	Essendine			3	22	46	95.0		
101.0	Tallington			3	25	20	88.0		
109.4	Peterborough	3	40	3	32	5	29.5		
113.3	Yaxley			3	36	12	73.6		
116.5	Holme			3	38	40	82 0	71.8	84.5
122.3	Abbots Ripton			3	43	5	71 0		
127.0	Huntingdon North	3	56	3	46	47	75.6		
129.9	Offord			3	49	17	71.7		
134.2	St. Neots			3	52	47	71.7		
138·4	Tempsford			3	56	3	79.5		
141.7	Sandy			3	58	42	59.2	70.0	81.8
144.7	Biggleswade			4	2	7	62.3		

(*) This speed was attained at the 91st mile post from London just north of Little Bytham Station. All speeds are taken from the dynamometer car records.

Miles from Leeds.	Station.	Times.					Speed-miles per hour.		
		Booked.		Actual.					
		H.	M.	H.	M.	S.	Passing.	Average between booking points.	Maximum attained between booking points.
148 8	Arlesey			4	5	47	75.2		
150.2	Three Counties			4	6	51	74.2		
154.0	Hitchin	4	17	4	9	56	71.0		
157.3	Stevenage			4	12	45	70.0		
160.9	Knebworth			4	15	40	72.2		
163.9	Welwyn			4	18	8	77.0	75.0	84.5
165 6	Welwyn Garden City			4	19	25	80.0		
168.2	Hatfield	4	28	4	21	18	80.0		
171.4	Brookmans Park			4	23	55	72.3		
173.1	Potters Bar			4	25	25	69.7		
175.5	Hadley Wood			4	27	15	77.5		
176.8	New Barnet			4	28	17	79.2		
177.6	Oakleigh Park			4	28	50	80.7		
179.5	New Southgate			4	30	20	83.8	65.0	83.8
181 0	Wood Green			4	31	24	81.0		
181.9	Hornsey			4	32	5	71.4		
182.5	Harringay			4	32	40	64.3		
183.4	Finsbury Park			4	33	30	60.5		
185.7	King's Cross	4	45	4	37	27	...		
185.7	*Leeds-King's Cross*	*2*	*45*	*2*	*37*	*19*	...	*70.8*	...
				Average booked speed : 67.5.					

[621.132.3 (.42)]

2. — P2 class 2-8-2 type express passenger locomotive No. 2002, « Earl Marischal », London & North Eastern Railway.

The second P2 class 2-8-2 type express passenger locomotive, No. 2002, « Earl Marischal », has recently been sent into traffic from the Doncaster works of the London and North Eastern Railway.

This engine incorporates many of the features of its predecessor, No. 2001, « Cock of the North », which was fully described in the November 1934 issue of this *Bulletin*.

By courtesy of Mr. Gresley, the Chief Mechanical Engineer of the Company, we reproduce a photo and drawing, together with a table of characteristics and dimensions of No. 2002 locomotive.

The three 21-inch diameter cylinders drive on to the second pair of coupled wheels, and the 9-inch piston valves are operated by Walschaerts-Gresley gear of similar pattern to that fitted on the L. N. E. R. *Pacific* engines. This is the main point on which engine No. 2002 differs from No. 2001, the steam admission and exhaust of which are controlled by means of poppet valves operated by rotary cam gear.

The tender of engine No. 2002 is of the high-sided, 8-wheeled type as fitted to the L. N. E. R. *Pacific* engines, with a water capacity of 5 000 gallons and a coal capacity of 8 tons.

LEADING DIMENSIONS AND RATIOS.

Grate.

Length on slope	7 ft. 2 in.
Width	6 ft. 11 3/4 in.
Grate area	50 sq. ft.

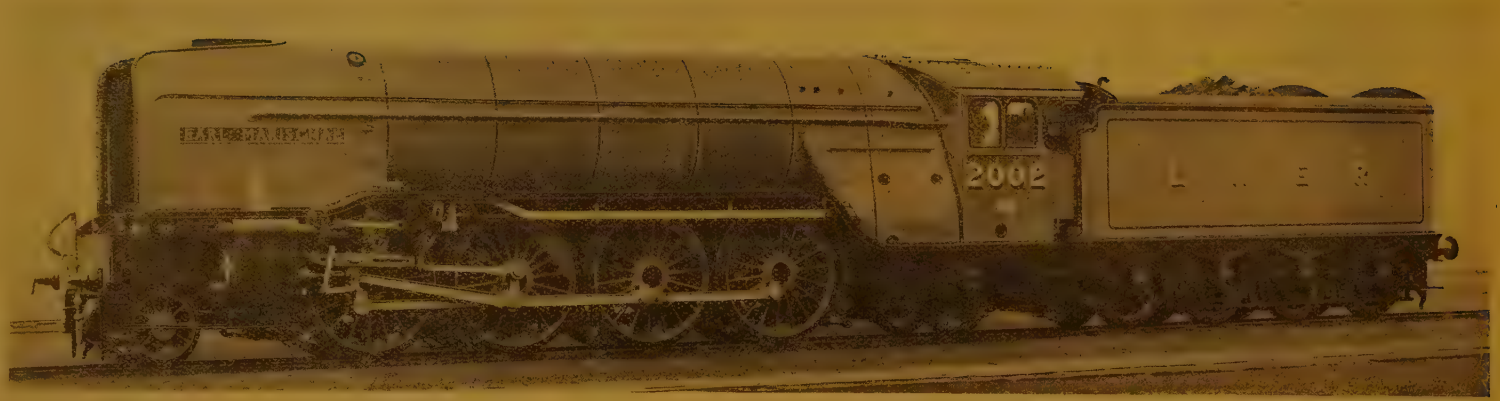


Fig. 1.

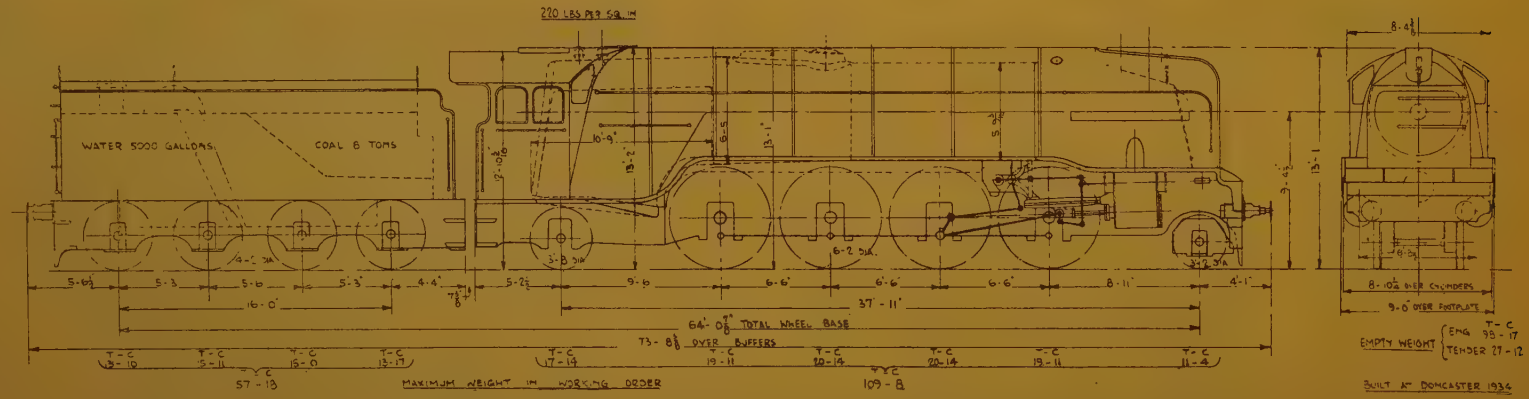


Fig. 2. — Side elevation and end-on drawing showing general arrangement.

Firebox.

Height of crown above foundation ring Front	6 ft. 8 13/16 in.
Height of crown above foundation ring Back	6 ft. 0 5/16 in.
Interior length at top	9 ft. 2 3/4 in.
Interior width at boiler centre	5 ft. 4 1/2 in.
Tickness of copper plates :	
Sides and back	9/16 in.
Tube plate	9/16 in. and 1 1/4 in.

Boiler.

Outside length firebox, overall	10 ft. 9 in.
Outside length firebox, at bottom	7 ft. 11 1/4 in.
Outside width firebox at bottom	7 ft. 9 in.
Diameter of barrel, maximum	6 ft. 5 in.
Length of barrel	19 ft. 0 in.
Thickness of barrel plates	23/32 in. & 25/32 in.
Thickness of wrapper plates	9/16 in.
Length of smokebox at bottom	8 ft. 11 in.

Tubes, small.

Material	Steel.
Number	121.
Diameter outside	2 1/4 in.
Thickness	10 I.W.G.

Tubes, superheater flues.

Number	43.
Diameter outside	5 1/4 in.
Thickness	5/32 in.
Length between tube plates	18 ft. 11 3/4 in.

Heating surface.

Firebox	237 sq. ft.
Tubes, 2 1/4 in.	1 354.2 »
Flues	1 122.8 »
Total evaporative H.S.	2 714.0 »

Superheater.

Number of elements	43.
Diameter inside	1.244 in.
Heating surface	776.5 sq. ft.
Total heating surface	3 490.5 sq. ft.
Two Ross « Pop » safety valves	3 1/2 dia.
Working pressure	220 lb. per sq. in.

Axles.

	Dia.		Length.
Journals, pony	6 1/2 in.	×	9 in.
Journals, coupled	9 1/2 in.	×	11 in.
Journals, trailing	6 in.	×	11 in.

Crank pins.

Outside	6 3/4 in.	×	6 in.
Inside	9 1/4 in.	×	6 in.

Coupling pins.

Leading	4 3/4 in.	×	4 in.
Driving	7 1/2 in.	×	4 1/2 in.
Intermediate	4 3/4 in.	×	5 in.
Trailing	4 3/4 in.	×	5 in.

Springs.

Pony : Helical, 10.3/16 in. long, free, 5 1/2 in. outs. dia., Timmis section.
Coupled wheels : Laminated 3 ft. 6 in. crs., 15 plates, 5 in. wide × 1/2 in. thick.
Trailing wheels : Laminated 4 ft. 6 in. crs., 14 plates, 5 in. wide × 3/8 in. thick.

Cylinders.

Number . . . . . 3.
21 in. dia. × 26 in. stroke.

Motion.

Type, outside	Walschaerts.
Type, inside	Gresley.
Type of valves	Piston.
Diameter of valves	9 in.
Maximum travel of valves	5 5/8 in.
Steam lap ins. cylinder	1 5/8 in.
Steam lap outs. cylinder	1 9/16 in.
Exhaust lap	Nil.
Cutt-off in full gear	65 %.
Tractive effort at 85 % boiler pressure	43 462 lb.
Total adhesive weight	180 320 lb.
Adhesive weight — Tractive effort	4.14.

Vacuum brake.

NEW BOOKS AND PUBLICATIONS.

[385. 1 (.43)]

Wirtschaftsführung und Finanzwesen der Deutschen Reichsbahn *(The economic and financial management of the Reichsbahn).* — Published by the General Management of the Deutsche Reichsbahn (German State Railway Company). — 1 vol. ($11\frac{1}{4} \times 8\frac{1}{4}$ inches), of 283 pages, with 53 tables and inset plates. — 1934, Berlin W 9, Verkehrswissenschaftliche Lehrmittelgesellschaft m. b. H. bei der Deutschen Reichsbahn, Voss-Strasse, 6. (Price : 15 Rm.)

The Society for the publication of articles dealing with the science of transport (Verkehrswissenschaftliche Lehrmittelgesellschaft m. b. H. bei der Deutschen Reichsbahn) has just issued, under the auspices of the General Management of the Reichsbahn, a detailed report on the economic and financial organisation of the German railways. A large part of this work deals with the historical development of all the essential questions of this important matter, which greatly adds to the interest this publication is bound to arouse.

The first part sums up the thesis to be developed in the rest of the book : the Reichsbahn is the greatest industrial undertaking in Germany, and from the point of view of the traffic, the most important railway company in the world. It is the greatest asset of the German State. Consequently, its economic operation is a vital question for the country, and this depends essentially on its financial and accountancy organisation. The report sets itself the task of showing that the Reichsbahn carries out its task thoroughly.

The second part is devoted to historical developments. First of all the pre-war period : the various railway systems are worked by the different German States. These were more or less prosperous years during which the traffic and receipts continuously increased, the financial organisation being dealt with as part of the general finances of each State.

After the difficult war period, the year 1920 marks the taking over of the different systems by the Reich; the amalgamation conditions are examined in detail. During the three following years, the finances of the Reichsbahn remained part of those of the State. This period saw the rolling stock reconstituted, and many large stations built or enlarged. It was also the time of the devaluation of the mark, during which the different managements of the Reichsbahn and even the main workshops had to issue their own paper money.

At the end of 1925, the finances of the Reichsbahn were separated from those of the Reich, and the Reichsbahn became the Deutsche Reichsbahn Gesellschaft (German State Railway Company). With the stabilisation of the currency came a period during which expenditure was strictly limited in every way. This period ended with negociations in connection with the Dawes plan and the consequent publication of laws concerning the Reichsbahn, which put its operating methods on truly industrial bases and in consequence led to the complete revision of the financial and accountancy services. The work describes briefly the measures taken, analyses the balance-sheets, the profit and loss accounts, and the statistics relating to receipts and expenditure for the 1924-1933 period. The policy followed during the world crisis is then defined, as the Reichsbahn found both its receipts and expenditure considerably reduced thereby.

The third part deals with the position of the Reichsbahn as compared with the other great German undertakings and

the great foreign railway companies.

This chapter brings out in particular the importance of the Reichsbahn in German economics, in which it is a very great force owing to the orders placed by it with the great industrial undertakings. In spite of the crisis, the total annual amount of these orders is still one thousand million marks.

The fourth part deals with the constitution of the Deutsche Reichsbahn Gesellschaft, with its financial relations with the State, the respective assets of the Company and the State, with the issue of stocks and shares and with the part played by the Company in war reparations. It goes on to deal with questions relating to the constitution of the reserve funds, loans and long-term contracts made by the Company, the interest it has in other spheres, such as the Transport Credit Bank, the Mitropa (Central European Sleeping-Car Company), etc...

In the fifth part, the part played by the Administrative Council and the General Management in financial questions is explained, and the organisation and duties of the Finance Department at the Headquarters is described.

The financial principles followed by the General Management of the Reichsbahn are dealt with in the sixth part. Programmes are drawn up to cover each branch of its activities. By means of the control exercised on the way these programmes are carried out and the examination of the daily, weekly, and monthly data prepared on the financial results, the General Management can take such steps as will ensure the financial results being influenced in the right direction. The complete financial programme as drawn up by the General Management is given as an appendix to the book.

The organisation of the Statistics Department is the subject of the seventh part. Particulars are given of the statistics compiled and the mechanical methods used in getting them out.

The eighth part is devoted to the accountancy and its principles, the legal bases being given first of all. The law by which the Reichsbahn was constituted lays down that the accountancy shall be on a truly industrial basis so that the financial position of the Company can be ascertained at any moment with certainty. The regulations concerning the capital, operating and renewal costs, the profit and loss account, and the preparation of the balance sheet are examined in detail.

The ninth part deals with the organisation of the Accountancy Department. After a brief historical sketch of the development of the accountancy regulations and their standardisation on the different systems, the principles of the accountancy method followed are examined and their pratical application considered. The accountancy methods and the different accounts are analysed, as well as the way they are applied in the different shops. Questions concerning the accountancy staff and auditing are also dealt with.

As an appendix to the book are given the balance sheets for 1931 of some of the great foreign railway companies, the list of the financial regulations governing the Reichsbahn, and a very complete bibliography relating to railway finance and accountancy.

This brief analysis makes it possible to get some idea of the amount of information and documentation to be obtained from this important publication. The text is illustrated by many statistical tables, diagrams, and synoptic tables, which make it easy and attractive to read. Owing to its very great value as a work of reference, this book will undoubtedly interest not only transport circles, but also everyone concerned with large industrial undertakings.

A. C.